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PhD dissertation

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Preface and acknowledgement

A Danish Technology director in a large manufacturing enterprise presents his version of challenges in product realization to me. From his point of view, it is essential for the company to be flexible enough to adapt new technologies and simultaneously improve quality and lead-time when introducing new products and processes. As I start inquiring into the organization, others across functions supports this story and explain how difficult it is to collaborate across development and production functions. Total Quality Management and Lean Thinking has influenced the company's production system for decades driving out excess resources for developing the production system from within. Instead, the company's production functions rely on specialist functions (Shop floor excellence and Technology) to support their development.

In another part of Denmark, A CEO in a medium sized manufacturing enterprise claims reluctant to tie designers in bureaucracy hampering their creativity and capability to meet customers' needs. It is an important competitive parameter for the company that they are capable of meeting customers demand for equipment adapted to their specific needs. The company has made a shift in strategic focus from single stand-alone projects to small, customized series of projects, where engineering reuses the design from previous customer projects. Market conditions has urged the company to maintain an ISO standard certification and implement World Class Manufacturing.

These vignettes represent the two manufacturing enterprises that were point of departure for my PhD project. Their challenges resonated with my experience from working with and within operations functions. I have developed processes in organizations under pressure for improving competitiveness throughout my working life. From my personal experience, organizational members such as managers, specialists and operators, tried their best to contribute to these development processes. I have met managers and employees that struggle to utilize their creativity within the boundaries of daily operations. The challenges in learning from experience are both rational and irrational as the findings from my master in Organizational Psychology showed. In my master thesis, I studied what hampered and promoted learning in a management team. Findings here from, revealed how the organizational learning process freeze and go into repetitive loops leading to limited exploration of the present situation and possible countermeasures when

division of responsibilities is unclear. These findings together with my working experiences fuelled my interest for organizational learning processes in daily operations. Thus, my curiosity was a primary driving force through this PhD project. Nevertheless, I could not have done it without the many people that have helped me throughout this project.

First, I would like to thank managers and employees in the two companies that so generously have answered questions, provided information and joined my experiments. I am very thankful for your willingness, openness and patience in our collaboration. Thank you MADE for providing the opportunity to make a contribution that can support manufacturing enterprises in Denmark and Professor Torben Petersen from Copenhagen Business School for leading work-package seven.

I would also like to thank all the inspiring scholars I have met in academia. I have learned so much from you the past three years. Thank you PhD Anna Sannö and Associate Professor Peter E Johansson for hosing me at Mälardalen University. Thank you Anna for sharing the ups and downs with me in the last phase of PhD life. And thank you Peter, our conversations about organizational learning helped me getting some of the last puzzles to fit into the picture.

An important source of inspiration to my work in this project came from conversations with Dr. Boaz Tamir from Israel Lean Institute about organizational development, the role of a process consultant and especially the scoping process. Thank you Boaz.

To guide and supervise me through my PhD project, I have been so lucky to have Professor Per Langaa Jensen, Associate Professor Christine Ipsen, Senior Researcher Kasper Edwards and Assistant Professor Giulia Nardelli as supervisors. You gave me constructive feedback that helped improve my work. Especially, I would like to thank you Christine who have encouraged me and enabled me to make hard decisions along the project.

Thank you to all the other PhD students I have met through the past three years. Together we have shared thoughts and tried to make sense of PhD life. Thank you Mette Bach Hansen and Supuck Prugsiganont for valuable encouragement and support as well as reminding me what really is important in life.

What is most important in life is family and friends. Thank you to my family, you always support and believe in me. Thank you to my close friends Liselotte Brydensholt Halkjær, Malene Amstrup and Vibeke Jørgensen for sharing thoughts, feelings and fantasies.

Finally and most importantly, thank you Court my beloved life companion, my two sons Nikolaj and Martin, and Rebecca my daughter in-law. You are truly the ones that makes life worth living. Thank you for your patience and trust in me.

Kgs. Lyngby, January 2018

Christina Villefrance Møller

Summary

Product realization processes are central to bringing new products to markets. Product realization processes comprises product development and production development. The problem is that manufacturing enterprises accelerate learning to reduce product realization lead-time. Practitioners struggle with cross-functional collaboration in solving problems that subsequently restraining continuous improvement and innovation (CII) in product realization. This research project apply an organizational learning perspective on cross-functional problem solving in product realization processes. The research project has two main objectives, first to develop and test a CII-program that integrates cross-functional work practices into product realization. The second objective is to enhance understanding of organizational learning processes in cross-functional and multilevel settings within manufacturing.

The Research project includes four literature studies and nine case studies in two manufacturing enterprises (a medium and a large sized). I studied literature in parallel with completing empirical studies applying an abductive strategy in the research design. I developed prototypes of a CII-program combining design thinking and lean thinking. Organizational members in the two manufacturing enterprises and I collaborated in a probe-and-learn process applying prototypes of the CII-program to generate learnings at early stages in the development process and to generate data for the research.

The first two exploratory case studied identified three main challenges in cross-functional work practices in product realization processes that restrained learning from experience of and experimentation in development projects. First, workflow and structure was sequential and partly overlapping causing coordination problems. Second, knowledge processes insufficiently spanned novelty and organizational boundaries. The third challenge related to collaboration between production and development functions in a climate of ambiguous or conflicting goals.

Secondly, two companies applied the CII-program in seven case studies to integrate new organizational practices into product realization processes. Applications of the CII-program showed that early management level scoping of cross-functional problem solving facilitate alignment across production and development functions. The case studies identified activities that facilitate

organizational learning processes in the CII-program. Furthermore, participants in the program gained insights about challenges in cross-functional collaboration and integrated new organizational practices into product realization processes.

For scholars and practitioners, this project contribute with learnings about the usefulness of developing a program in a probe-and-learn process with prototypes. In addition, this project enhance the field of Operation Management with understandings of organizational learning processes in cross-functional and multilevel settings within manufacturing. For practitioners, this project contribute with a CII-program that combines design thinking and lean thinking in a creative problem solving process in product realization processes.

Dansk resume

Produkter bringes til markedet gennem produktrealiseringsprocesser som omfatter produktudvikling og produktionsudvikling. Dette projekts problemstilling tager udgangspunkt i fremstillingsvirksomheders behov for at accelerere læringen og reducere gennemløbstiden for produktrealisering. I virksomhederne er samarbejdet omkring løsning af problemer på tværs af funktioner udfordret. Dermed hæmmes løbende forbedringer og innovation (continuous improvement and innovation – CII) af produktrealiseringen. Dette forskningsprojekt anvender et organisatorisk læringsperspektiv på tværfunktionel problemløsning i produktrealiseringsprocesser. Forskningsprojektet har to hovedmål: at udvikle og afprøve et CII-program, der integrerer arbejde på tværs af funktioner i produktrealiserings processen, samt at forbedre forståelsen af organisatoriske læringsprocesser på tværs af funktioner og organisatoriske niveauer i fremstillingsvirksomheder.

Forskningsprojektet omfatter fire litteraturstudier og ni casestudier i to fremstillingsvirksomheder (mellemstor og stor). Jeg har studeret litteraturen parallelt med empiriske undersøgelser og anvendt en abduktiv strategi i forskningsdesignet. Jeg udviklede prototyper af et CII-program, der kombinerer design tænkning og lean tænkning. Medarbejdere og ledere i de to fremstillingsvirksomheder og jeg samarbejdede i en undersøg-og-lære-proces. Anvendelsen af prototyper af CII-programmet gav os erfaringer med programmet på et tidligt stadie i udviklingsprocessen. Derudover genererede anvendelsen af CII-programmet data til analysen af de organisatoriske læringsprocesser.

De to første case studier identificerer tre hovedudfordringer i arbejdet på tværs af funktioner i produktrealiseringsprocesser. Disse udfordringer begrænser læringen fra erfaring og eksperimenter i udviklingsprojekter. For det første er arbejdsprocesser og strukturer sekventielle og delvist overlappende, hvilket forårsager koordinationsproblemer. For det andet spænder videnprocesser ikke tilstrækkeligt over graden af nyhed og organisatoriske grænser. Den tredje udfordring vedrører samarbejde mellem produktions- og udviklingsfunktioner i et klima af tvetydige eller modstridende mål.

I de efterfølgende syv casestudier anvendes CII-programmet i de to virksomheder for at udvikle ny organisatorisk praksis i produktrealiseringsprocesser og integrere procesudvikling i det daglige

arbejde. Anvendelse af CII-programmet letter problemløsning på tværs af produktions- og udviklingsfunktioner ved at rammen for problemløsningen tidligt sættes på ledelsesniveau. Casestudierne identificerede aktiviteter, som understøtter organisatoriske læringsprocesser i CII-programmet. Endvidere fik deltagerne i programmet indsigt i udfordringerne i samarbejdet på tværs af funktioner og integrerede nye organisatorisk praksisser i deres produktrealiseringsprocesser.

For akademikere og praktikere bidrager dette projekt med læring om udvikling af et program i en undersøg-og-lær-proces med prototyper. Derudover bidrager dette projekt til Operation Management med forståelsen af organisatoriske læringsprocesser på tværs af funktioner og organisatoriske niveauer i fremstillingsvirksomheder. Til praktikere bidrager dette projekt med et CII-program, der kombinerer design tænkning og lean tænkning i en kreativ problemløsningsproces i produktrealiseringsprocesser.

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Part I Introduction

The purpose of this first part of the dissertation is to introduce you (the reader) to the research topic and problem. The key message is that conditions and technological opportunities urge manufacturing enterprises to continuously reduce lead-time and accelerate learning in product realization processes. In part I, I first explain the background for the project and its relevance for manufacturing enterprises. New technological opportunities in product realization invigorate the (ancient) productivity dilemma of trading off flexibility/innovation and efficiency. Second, I present current research that only to a limited extent focusses on cross-functional work practices in product realization processes and present the overall research question. Third, I define central concepts within organizational learning and knowledge management as these two fields serve as perspectives on the phenomena I study in renewal of product realization. Fourth, I present the empirical field of product realization in manufacturing enterprises that I am investigating in this project. In the fifth section, I present the two main objectives for this research project. The first objective is to develop and test a continuous improvement and innovation (CII) program that integrates developing product realization processes in daily work. The second objective is to investigate organizational learning processes as they take place in practice in manufacturing. In this fifth section, I also present four sub-questions that supports answering the overall research question. Two sub-questions provides theoretical ground for the following two sub-questions. The first two sub-questions characterize cross-functional work processes in product realization respectively organizational learning processes that supports integrating new organizational practices in product realization. The other two sub-questions provides empirical explanations of cross-functional challenges in product realization and activities that facilitates integrating new organizational practices in product realization. Finally, this introductory part sums up the structure of the dissertation and describes how the chapters address the research question and four sub-questions.

1 Introduction

This project responds to manufacturing enterprises' call for ways to speed up time elapsing from an idea for a product emerge to delivery at the customer. Product lifecycles shortens and technological achievements contribute to renewing products constantly (Cole 2002; Porter & Heppelmann 2014; Porter & Heppelmann 2015). For decades scholars has emphasized that the time it takes to realize product ideas (time-to-market) is crucial for manufacturing enterprises competitiveness (Clark & Fujimoto 1988; Adler 1995; Cole 2002). A core process for bringing new technologies in products and production processes to market is product realization that comprise product and production development (Tomovic & Wang 2009; Bellgran & Säfsten 2010; Stark 2016). Scholars argue that rapid changes and shortened product lifecycles calls for renewing knowledge and accelerating learning (Cole 2002; Sanz-Valle et al. 2011). However, practitioners and scholars reports challenges in cross-functional collaboration on solving problems that subsequently restraining continuous improvement and innovation in product realization (Adler 1995; Adler et al. 1999; Lu & Botha 2006; Bellgran & Säfsten 2010).

In light of challenged cross-functional problem solving, it is therefore interesting that literature within operation management, knowledge management and organizational learning primarily study product development separated from production (Lu & Botha 2006; Dekkers et al. 2013). Research do not pay as much attention to the development process of production systems as to product development (Bellgran & Säfsten 2010). Furthermore, process development is only mentioned as a part of the product development process (Lu & Botha 2006; Dekkers et al. 2013). Few scholars (Adler 1995; Liker et al. 1996; Carlile 2004; Lu & Botha 2006; Morgan & Liker 2006; Bellgran & Säfsten 2010) study the integration between product development, production development and production. Adler (1995) propose a taxonomy for four modes of interaction (standards, schedules, mutual adaption and teams) across functions in three phases (pre-project, product and process design, and manufacturing). Boer et al. (2001) suggests that e.g. manufacturing is both a source of information and a contributor to product innovation especially if short time-to-market is demanded. Process development or production development describes the step between product development and production (Carlile 2004; Lu & Botha 2006; Bellgran & Säfsten 2010). Integrating these processes is emphazised within Cuncurrent Engineering (Boer et al. 2001; Valle & Vázquez-Bustelo 2009) and Lean Product and process development that use Toyota as rolemodel (Liker et al. 1996; Morgan & Liker 2006). Though integration among mutual projects has increased attention (Boer et al. 2001) e.g. sharing lessons learned (Chirumalla 2017) and product lifecycle management (Stark 2016).

Both knowledge management and organizational learning is associated with innovation and both contribute to literature on product realization (Lavie et al. 2010; Valaski et al. 2012; Dekkers et al. 2013; Costa & Monteiro 2016). Knowlegde management literature study renewal of organizations knowledge base through knowledge creation and generation (Pitt & MacVaugh 2008; Boer et al. 2001; Carlile 2004). Literature within organizational learning addresses organizational ambidexterity in context of manufacturing (e.g. Katila & Ahuja 2002; Benner & Tushman 2002). Scholars describe organizational ambidexterity as managing exploration and exploitation as two organizational behaviors (March 1991; Gupta et al. 2006; Raisch & Birkinshaw 2008; Lavie et al. 2010). Some scholars connect exploitative behavior to process management and incremental improvements and explorative behavior to product development and radical innovation suggesting that these behaviors are split in time and structure (Benner & Tushman 2003; Lavie et al. 2010). Where others suggest that managers should be capable of both (Gibson & Birkinshaw 2004). Few scholars take the actual work processes into account such as Adler et al. (1999) who described the relationship between product development and production at Toyota.

Benner & Tushman (2015) revising their initial theories suggest that scholars takes a more problem focus approach in order to develop fresh theories on innovation and organizations. Amon identified issues relevant for research is what they call the “false promise of universal best practices” (Benner & Tushman 2015). “Faced with uncertainty, managers search for solutions to their challenges often by looking to “experts,” such as consultants, or to other successful organizations for promising approaches” they claim (Benner & Tushman 2015, p. 502). Benner and Tushman (2015) warn that implementing universal programs can potentially deliver unexpected outcomes or even be harmful for organizations if the conditions in the organizational context is not properly understood. In a following discussion Benner & Tushman (2015) propose that modularized products and broadly dispersed problem-solving knowledge change the locus of innovation to communities or markets spanning organizational boundaries.

An organizational learning perspective is therefore useful for exploring gaps between production and developing products and production processes to understand what restrain problem solving in product realization. The main purpose of this project is to renew product realization and gain insight into integration of cross-functional process improvement in daily work.

I position this project within operation management and apply an organizational learning perspective on product realization processes. I use organizational learning to describe problem solving in product realization processes. My focus is on the organizational learning that the organizational members integrate into organizational practices and not the individual experiences and learnings from participating in a learning process. In addition, I touch knowledge processes across organizational functions in product realization processes and in connection to solving problems in product realization processes. Thus, knowledge processes support the organizational learning process. Organizational learning processes explain the collective process of learning from experience and experimentation through explorative feedforward and exploitative feedback processes (Crossan et al. 1999).

It is my intention to provide help for practitioners solving problems in development processes across functions and extend the conversation about cross-functional continuous improvement and innovation within operation management. I propose a program for integrating cross-functional problem solving in product realization processes into daily work. Organizational members across functions and levels solve practical problems in product realization processes as part of a continuous improvement and innovation (CII) program. The program ensures applicability in practice through learning from practical experience of what worked and did not work and from experiments carried out in specific daily work situations. Explorative and exploitative learning processes supports integrating continuous improvement and innovation into product realization processes. The outcome of the CII-program deliver practical solutions to identified problems, insights about product realization processes, and learning from experience of renewing product realization processes.

In the following, I first elaborate on the background for this project. Secondly, I introduce current research on organizational learning processes in a product realization context and propose a research question. Thirdly, I define key concepts within the fields of organizational learning. Fourthly, I then describe the empirical field of continuous improvement and innovation in cross-functional contexts. Fifthly, I present the research objectives and four sub-questions that contribute to answer the research question. Then in the summary, I shortly present the content of the remaining dissertation.

1.1 Background

After a period with intense focus on surviving the Financial Crisis, manufacturing enterprises now has to reinvent themselves in light of emerging new technological opportunities (PwC 2013, McKinsey Global Institute 2012, BCG 2016). When new technology emerges, as is the present situation for manufacturing enterprises, the focus is first on product technology and innovations, second on efficiency in production, and third on reducing costs (Bellgran & Säfsten 2010, p. 131). Porter & Heppelmann (2014; 2015) promotes speed and flexibility as key to succeed with new technologies. Speed in product and process development imply experimenting (fail fast) on one hand and managing a vast abundancy of organizational agendas on the other hand (Porter & Heppelmann 2015).

Even though flexibility and innovation have increasing importance in manufacturing enterprises, they still emphasize quality and dependability as the highest competitive priorities (Netland & Frick 2017). Netland and Frick (2017) suggests that manufacturing enterprises trade off cost at the expense of speed and dependability in times of economic decline and give way for other competitive priorities in times of increasing prosperity (Netland & Frick 2017). Proposing that manufacturing enterprises are not to lose sight of efficiency while emphasizing innovation in product realization (Netland & Frick 2017). Adding to the trade-off discussion of resources, Schmenner (1993) propose that increasing speed and flexibility is an ongoing learning process for developing production, which imply pushing possibility frontiers outward improving quality, lowering costs. Clark & Fujimoto (1991) address lead-time, total product quality and productivity as a key factors influencing product development performance. Lead-time is defined as “the calendar time required to define, design, and introduce the product to market" (Clark & Fujimoto 1991, p. 69).

Through the years, scholars has studied the relationship between product and process development and innovation. In their classic article, Utterback and Abernathy (1975) proposed a dynamic model of process and product innovation proposing a mutual relationship between innovation processes, competitive strategy, and state of production process development on a company level (Utterback & Abernathy 1975). Production processes develops over time in an evolutionary pattern characterized by routinization and standardization of products and processes (Utterback & Abernathy 1975). However, as processes becomes increasingly integrated in a system so that changes becomes costly and difficult to implement (Utterback & Abernathy 1975). Products develop similarly through refinements for improving product performance, enhancing variety and standardization (Utterback & Abernathy 1975). As a product matures, it becomes increasingly difficult to introduce entirely new products having the same performance (e.g. quality, availability and cost) as the replaced product (Utterback & Abernathy 1975). New technology might initiate major changes in both products and production processes (Utterback & Abernathy 1975).

Clark and Fujimoto (1991) compare the performance of product and process development in the automotive industry and find that integrated problem solving across functions characterized those with outstanding performance. Pisano and Wheelwright (1995) recognize the interdependency between product and manufacturing-process development in their study of high-tech industries. From their studies, they saw that: "In many high-tech markets in which product technology is rapidly evolving, manufacturing-process innovation is becoming an increasingly critical capability for product innovation." (Pisano & Wheelwright 1995).

MADE (Manufacturing Academy of Denmark) is a collaborative initiative that support research in digitalization and development of new technologies. The purpose is to make Denmark attractive for manufacturing enterprises (Appendix A MADE). This project is part of MADE's work package seven titled "The "new" manufacturing paradigm" and imply collaboration with two companies associated with the work package. A preliminary objective for this project was to investigate: "How can Danish enterprises develop production processes and simultaneously secure stable and efficient processes?" Developing product realization processes in a continuous improvement and innovation program fulfill that purpose and is this projects contribution to MADE's work package seven. I carry out research in collaboration with a large and a medium sized manufacturing enterprise.

Research for this project is carried out in collaboration with a large (company A) and s medium-sized (company B) manufacturing enterprise. I instantly started my research by visiting the two companies to clarify their expectations to my research. A continuous dialog between us aligned the companies' expectations to me, and my contributions to them throughout the project. Also collaborating with the work package leader at another university together with my own supervisors contribute to the complexity of goals for the project. The GTS-institute, Force Technologies, was not part of developing the program though served as a partner in disseminating the CII-program to other SMEs within MADE as an extended test of the program. The two companies participating in my research project both wanted to have "organizational ambidexterity" struggling to understand what it was and how they could "get it".

1.2 Current research focus

Development work such as renewing product realization processes comes under pressure to accelerate learning when manufacturing enterprises product lifecycle shortens (Cole 2002). Reducing lead times in the product lifecycle involves the relationship between product development and production (Adler 1995). Scholars and practitioners has suggested different models for e.g. product development (Ulrich & Eppinger 2012). These models suggests how manufacturing enterprises can organize and structure their development work. Some scholars also suggest that manufacturing enterprises continuously improve product development processes (Morgan & Liker 2006). However, limited research study continuous product innovation as part of daily development work (Cole 2002) and even less take continuous innovation of development work into account. Furthermore, limited literature describes how manufacturing enterprises both can continuously improve and continuously innovate development work as an integrated part of daily work.

I use the notion “product realization” to emphasize that product development involves production development designing and specifying how a product is manufactured on a conceptual and tangible technology level (Bellgran & Säfsten 2010). Early product design decision influence a majority of production costs (Bellgran & Säfsten 2010). Scholars recommend that production engineering and production development functions are involved in product development projects at an early stage (Bellgran & Säfsten 2010). Early involvement of production engineering and production development can ensure manufacturability of new products (Bellgran & Säfsten 2010) and ease the integration in existing production facilities in Production.

Development work in this project comprises renewing processes for developing products and production processes throughout a product lifecycle. Production development is a logic extension of product development when it comes to developing new production processes or adjusting existing production processes for new products. Production development processes comprise designing and specifying how to manufacture a product on a conceptual and tangible technology level (Bellgran & Säfsten 2010; Dekkers et al. 2013; Lu & Botha 2006). According to Lu & Botha (2006) process design additionally include translating the product design into organizational capabilities.

In a systems perspective on organizations, an organizational system comprise the entities and the processes in the organization. As such, I consider the product development system and the production system as two separate, however, interrelated sub-systems within a manufacturing system. Where the organizational system is a broadly used term for describing the interrelationship between purpose, process or people (Bartlett 1994; Bartlett 1995; Ghoshal 1995) or people, processes and technology (Morgan & Liker 2006) or capability, process, structure, people and rewards (Galbraith et al. 2002). In this way, a systems perspective underline that change in e.g. processes depends on changes in people’s behavior, the purpose and recognition they get from it, the structural constrains or opportunities, and people’s ability to do what is expected of them. In a systems perspective, physical processes, workflows, and information flows links management together with development of the system. However, it is primarily practitioners and scholars within Lean product development that use the notion “product development system”.

An entire academic field has grown from studying organizational ambidexterity as an organizations capability to balance, trade off, or reconcile efficiency (or performance management) and innovation (Almahendra & Ambos 2015). The field focuses on two types of learning behaviors for organizational learning (O'Reilly & Tushman 2013; Simsek 2009; Raisch & Birkinshaw 2008; Almahendra & Ambos 2015). Trial-and-error experimentation and search for knowledge is characterized as an explorative learning behavior related to innovation and organizational refinement and use of existing knowledge is an exploitative learning behavior related to efficiency (Levitt & March 1988; March 1991; Rodan 2005; Almahendra & Ambos 2015). Researchers tends to split explorative and exploitative learning behaviors organizationally or temporarily, and connecting learning behaviors to an organizations evolutionary or revolutionary change (O'Reilly III et al. 2009; Tushman & O'Reilly III 1996; Gupta et al. 2006). Others propose managers should be capable of handling both types of learning behavior (Gibson & Birkinshaw 2004; Birkinshaw & Gupta 2013; O'Reilly III & Tushman 2011). Even though researchers have put a lot of effort into defining and conceptualizing organizational ambidexterity, the field still lack operationalization (Birkinshaw & Gupta 2013) e.g. Gupta (2006) proposes further research in achieving ambidexterity at functional (micro-) level in other functions than R&D. While most research focus on organizational ambidexterity in a strategic and inter-organizational perspective, only few has studied how manufacturing enterprises create, lose and regain balances of exploration and exploitation at operational level (Gupta et al. 2006; Birkinshaw & Gupta 2013). Only two examples of developing programs promoting organizational ambidexterity have been found and they emphasize management capabilities (Pellegrinelli et al. 2015; Dover & Dierk 2010). However, by focusing on management capabilities these authors indirectly emphasize individual learning in contrast to organizational learning. As Lahteenmaki et al. (2001) show, models for organizational learning processes describe learning of individuals in organizational settings rather than the learning of organizations. Limited research study organizational learning processes (Jiménez-Jiménez & Sanz-Valle 2011).

However, limited research propose practical applications that integrate cross-functional work practices into product realization processes. Furthermore, limited research propose practical application of exploration and exploitation in an organizational learning process. As there is insufficient answers for manufacturing industries' challenges in literature, the overall research question for this project is as follows:

> RQ: "How can manufacturers integrate new organizational practices into product realization processes?"

For practitioners, this project contribute with a CII-program that combines Design Thinking and Lean Thinking in a creative problem solving process that are useful for integrating cross-functional work practices into product realization processes. For scholars and practitioners, this project contribute with learnings about the usefulness of developing a program in a probe-and-learn process with prototypes. Furthermore, this project enhance the field of Operation Management with understandings of organizational learning processes in cross-functional and multilevel settings within manufacturing.

1.3 Defining key concepts

Literature within organizational learning and knowledge management is overlapping and interrelated (Chiva & Alegre 2005; Hislop 2013). Within organizational learning literature, organizations are "holding environments for knowledge" and represent knowledge directly (Argyris & Schon 1996). The organization codify and accumulate knowledge in procedures, norms rules, and forms (March 1991; Schein 2010) and organizational memory is a map of the past captured in individual memory, files documents and IT-systems (Argyris & Schon 1978).

In this project, I use organizational learning to describe the process of developing product realization processes within the CII-program. Knowledge processes such as sharing, transfer, acquisition, generation, creation and reuse describes specific activities that takes place in both product realization processes and in organizational practices renewing product realization processes. The outcome of the organizational learning processes in the program constitutes practical solutions to identified problems, insights into product realization processes, and organizational members' experience of participating in renewing product realization processes.

Organizational learning

Organizational learning is the chosen primary perspective on product realization improvement in this research. I will therefore first present definitions of learning and organizational learning, and then second discuss how authors distinguish between individual learning and organizational learning. As a third topic in this section, I will discuss how the organizational learning perspective applied in this project distinguishes from the perspective of communities of practice.

Argyris and Schon (1978) define organizational learning as "… a process in which members of an organization detect errors or anomalities and correct it by restructuring organizational theory-of-action, embedding the results of their inquiry in organizational maps and images". Where Argyris and Schön (1978) emphasize the origin of learning from experience, Dixon (1994) in her definition connects organizational learning processes to an intentional outcome. Dixon (1994) defines organizational learning as "… the intentional use of learning processes at the individual, group and system level to continuously transform the organization in a direction that is increasingly satisfying to its stakeholders" (Dixon 1994).

In an organizational learning perspective, authors builds on the assumption that organizations are more than collections of individuals (Argyris & Schon 1978; Dixon 1994; Crossan et al. 1999). The organization is an open system interacting with the environment on all levels of the organization (March 1991; Argyris & Schon 1978; Dixon 1994). Organizational systems are able to learn from experience such as adapting new knowledge from outside the organization (Morgan 1997; Argyris 2008). Pedler, Bourgoyne and Boydell (1991) define the learning organization as 'an organization that facilitates the learning of all its members and continuously transforms itself' (Lahteenmaki et al. 2001).

Individuals learn though "[s]ome learning is embedded in the systems, structures, strategy, routines, prescribed practices of the organization, and inscribed practices of the organization, and investments in information systems and infrastructure." (Crossan et al. 1999, p. 529). Organizational members collaborate on integrating their learnings into practices in product realization processes. Individual learning reflects on organizational members' behaviors and influence the behavior of other organizational members.

However, these individual learnings is only part of the organization as long as organizational members expressed or shared their knowledge with others. Learnings embedded in the organizational member as tacit knowledge follows the individual and not the organization. I use the term "organizational members" to integrate people at all levels whatever role and responsibility they have in the organization (Dixon 1994). I specify roles and responsibilities when important. Otherwise, I consider organizational members as contributing equally to developing product realization processes and their development.

Knowledge management processes

Knowledge is "justified true belief" (Nonaka 1994), and the capacity to define a situation and act accordingly (Nonaka & von Krogh 2009). This project apply a knowledge management perspective on product realization to study knowledge processes associated with cross-functional work practices in product realization processes. In the following, I first shortly presents different types of knowledge relevant for this context. Then I discuss how the key concept of knowledge and knowledge processes relates to organizations.

Polanyi (1983) coined the distinction between "tacit" and "explicit" knowledge. "Tacit" knowledge is unspoken and connected to the body in contrast to "explicit" knowledge that is spoken or written in a dialog between people (Nonaka 1994). Blackler (1995) propose another dimensions of knowledge as embrained knowledge depending on conceptual skills and cognitive abilities, embodied knowledge being action oriented, encultured knowledge referring to the process of achieving shared understanding, embedded knowledge residing in systemic routines, and encoded knowledge being information conveyed by signs and symbols.

Nonaka (1994) defined knowledge as justified belief, however, in an organizational context, knowledge is justified by someone that has the authority to justify what the organization know (Gourlay 2006). In this perspective, knowledge justified by managers from different parts of an organization can contradict each other and cause tensions between organizational functions (Gourlay 2006). In addition, management has no direct influence on justifying individual employees tacit knowledge that employees gain before entering the organization (Gourlay 2006).

Within knowledge management literature, scholars propose alternative definitions of “knowledge” as organized and analyzed information, sets of insights, experiences, and procedures considered correct, true and applicable for action such as problem solving or decision-making (Carayannis 1999). In an organizational setting, knowledge as an asset can be shared between individuals and groups or governed by management (Foss et al. 2010). Knowledge is “a mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information.” a definition of knowledge proposed by Davenport and Prusak (1998) (Xu et al. 2010) . In a pragmatic view, knowledge is localized, embedded, and invested in practice (Carlile 2002).

Scholars propose that organizational knowledge is the collective sum of assets connected to organizational members, intellectual property, infrastructure market as well as organizational design (Carayannis 1999). Knowledge as business processes are activities that enable the creation, storage, transfer, distribution, adaptation and application of knowledge (Henriksen & Rolstadås 2009). Costa & Monteiro (2016) studied the relationship between innovation and six knowledge management process (acquisition, storage, codification, sharing, application, and creation). Foss et al. (2010) adds knowledge governance and generation to the list of knowledge management processes, which I in the following refer to as knowledge processes.

1.4 Empirical field of investigation

The empirical field of investigation in this research is product realization processes in manufacturing enterprises. A new product, whether a completely new or a revised version of an existing product, initiates revision or development of production processes (Hill 2000, p. 33) as part of the production system (Bellgran & Säfsten 2010, p. 47). Research on manufacturing strategies prescribe how management can decide upon appropriate production processes according to the type of product, product mix, or production volume (Hill 2000; Miltenburg 2005).

I define product realization as a process transforming knowledge and materials into new products and production processes in production as well as new knowledge and human experiences of what worked and did not work.

The product realization process constitutes the context. In this context, organizational members learn from their experience and from experimenting when they develop a specific product realization process as part of the organizational learning program. The organizational members develop the product realization process by solving specific problems in a real life setting.

It is the assumption in company A that Technology has not shown its worth until production developments is operating as expected. This assumption draws attention to the factories' role in contributing to development of product realization processes. One opinion within Technology states that due to increasing specialization in functions, specialist introducing new products and processes in production has come too "far" away from daily work, which then stifle transition to production and learning from experience in production.

In company B, each customized order project reuse design and documentation from previous projects. Project managers often claim that designs for one project is 80% identical to previously delivered projects. As one project manager said: "How do you navigate through all what is previously made? You can ask someone who has been here for 25 years, but what if he is not there anymore." Simultaneously, a team manager in assembly complains that the same errors in design such as missing holes recur repeatedly even though he reports the errors to designers.

Within literature on manufacturing strategy, production systems achieve realignment toward market expectations through making improvements and increasing manufacturing capabilities (Miltenburg 2005). Continuous Improvement is a term often used in connection with problem solving in Lean Thinking (Womack 2003) as well as an organization-wide process of focused and sustained incremental innovation (Bessant & Caffyn 1997).

1.5 Research objectives

I have two main objectives for this research project. The first objective is to develop and test a CII-program that integrates cross-functional work practices into product realization. The second objective is to enhance understanding of organizational learning processes in cross-functional and multilevel settings within manufacturing.

Four sub-questions corresponds to these to objectives in shifting between literature studies and empirical studies. First, I clarify characteristics of cross-functional work processes in product realization (RQ1) in literature and explore the challenges in product realization empirically (RQ2). This understanding of the challenges and causes influencing the challenges founds the ground for the next two sub-questions where I first study literature on to identify activities that facilitate organizational learning processes (RQ3) for prototyping and testing a CII-program (RQ4). The following four sub-questions supports the research question:

RQ1: What characterizes cross-functional work practices in product realization?
RQ2: What challenge cross-functional work practices in product realization in a medium sized Engineer-To-Order respectively a large Make-To-Stock manufacturing enterprise?
RQ3: What activities facilitate organizational learning processes in product realization?
RQ4: What activities facilitate integrating new organizational practices in product realization?

As a pre-step, I initiate my research by entering two case companies associated to the MADE work package. At this early stage, my intention is to clarify in what situations I can observe explorative and exploitative processes. Few case studies within organizational ambidexterity such as (Gibson & Birkinshaw 2004; Benner & Tushman 2003) give rich empirical descriptions on organizational learning. However, these empirical studies are done in large manufacturing enterprises and focus more on the outcome (innovation and efficiency) (Benner & Tushman 2003; Benner & Tushman 2002), organizational design (O'ReillyIII et al. 2009; O'Reilly & Tushman 2013) and management capabilities (Gibson & Birkinshaw 2004; O'ReillyIII & Tushman 2011) and not the organizational learning process itself. As emphasized by Gupta et al. (2006) empirical case studies can contribute to literature through rich investigations of diverse organizations in various organizational levels.

For the first sub-question, I identify characteristics for cross-functional work processes in product realization. The literature study reveal that not many papers takes a life-cycle perspective on cross-functional product realization. (Examples and references to Bellgran).

For the second sub-question, I study cross-functional product realization in a small respectively a large manufacturing company. This study provides me with an understanding of the problems in product realization processes. I investigate daily work where product realization spark a tension between developing routines and deliberately breaking them regularly. However, when organizational members stand in situations e.g. when new technology enters the shop-floor, solutions are unknown and experimentation necessary (Porter & Heppelmann 2015). Routinization leads to assumed predictability where experimentation carry the risk of failing and as such is unpredictable (Hislop 2013; Crossan et al. 1999; Levinthal & March 1993). Consequently, the routinized and institutionalized leaning comprise a rigidity necessary for efficiency, however, also possibly generating an inability to question the institutionalized norms for further development Crossan et al argue (1999: 534). In addition, Nonaka (1994) describe a “ba” as the place where learning happens. Within operational management and especially literature describing Lean Thinking (Womack et al. 2007; Shingo 1988; Liker 2011) refer to continuous improvement as a way of creating learning opportunities in daily work. Authors conduct empirical studies of the cross-functional aspects of continuous improvement (Voss et al. 2011), and continuous improvement of product and process development (Helander et al. 2015; Liker 2011). With reference to Toyota production systems superiority, continuous improvement and Lean justifying conceptualized learning opportunities such as Kaizen and Kaikaku (Yamamoto & Bellgran 2013). However, utilizing organizational members own creativity in the organizational learning process is lacking.

Finally, for the fourth sub-question, I investigates how managers can authorize and scope an organizational learning process. Organizations often split the roles of performing routine from non-routine tasks in different organizational functions (Mintzberg 1979). Subsequently, management becomes key facilitators of collaboration and knowledge sharing across organizational boundaries. In this perspective, managers can perceive knowledge as an asset or capability belonging to his or her jurisdiction. Nonaka (1994) refer to knowledge as “justified beliefs”. Reduction of interaction with colleagues (Taylor) from other functions leads to alienation hampering knowledge sharing. Unless acute issues (breakdown) emerge and calls for the presence of specialists. Research acknowledge, that knowledge has to be justified and change processes authorized (Nonaka 1994; Dixon 1994; Cohen & Levinthal

1990). However, authorizing and scoping an organizational learning process is absent from literature. These four sub-questions will contribute to the overall research question of this project.

1.6 Structure in the dissertation

The dissertation comprise of six parts: Introduction, Theory, Methods, Findings, Analysis, and Discussion and conclusion. These six parts follow a classical structure of academic work. Within each of the six parts, I have divided the topics into chapters. Table 1 outlines the six parts of the dissertation, place the chapters accordingly and present the purpose of each part.

1. Outlining the six parts of the dissertation and placing the chapters accordingly.

Parts		***Chapters***		***Purpose of the part is:***
I.	Introduction	1.	Introduction	to introduce the practical and theoretical foundation for the research.
II.	Theory	2. 3. 4. 5.	Cross-functional work practices in product realization Knowledge processes in product realization An organizational learning perspective on integration of new work practices Continuous improvement and innovation programs	to clarify the theoretical ground for the empirical studies in two manufacturing enterprises
III.	Methods	6. 7.	Methodology Research Design	to create transparency of research done for this dissertation
IV.	Case description and program design	8. 9.	Case description of challenges in two manufacturing enterprises Designing a continuous improvement and innovation program	to present findings of the empirical studies
V.	Analysis	10. 11.	Analyzing challenges in two manufacturing enterprises Analyzing organizational learning processes in the CII-program	to present the analysis of the empirical studies
VI.	Discussion and conclusions	12. 13.	Discussion Conclusion	to discuss findings. to draw conclusions of the research question and present contributions

The purpose of the Introduction is to set the scene by introducing the practical and theoretical foundation for research in this project. At this point, I have described the empirical and theoretical background, described current research, defined key concepts within organizational learning and knowledge management, presented the empirical field I investigate, and stated my objectives for research. Furthermore, I have presented a research question supported four sub-questions. Table 2 present the research question and four sub-questions and relates them to the chapters in the dissertation.

2. The research question and four sub-questions and related chapters.

Theoretical research questions	***Literature study***	***Empirical research question***	***Findings, analysis and contribution***
RQ1: What characterizes cross-functional work practices in product realization?	2. Cross-functional work practices in product realization	RQ2: What challenge cross-functional work practices in product realization in a medium sized Engineer-To-Order respectively a large Make-To-Stock manufacturing enterprise?	8. Case description of challenges in two manufacturing enterprises 10. Analyzing challenges in two manufacturing enterprises
RQ3: What activities facilitate organizational learning processes in product realization?	3. Knowledge processes in product realization 4. An organizational learning perspective on integration of new work practices 5. Continuous improvement and innovation programs	RQ4: What activities facilitate integrating new organizational practices in product realization?	9. Designing a continuous improvement and innovation program 11. Analyzing organizational learning processes in the CII-program
RQ: How can manufacturers integrate new organizational practices into product realization processes?			12. Discussion 13. Conclusion

In the theory part of the dissertation, chapter 2 addresses the first sub-question RQ1 and defines the theoretical ground for the empirical sub-question RQ2. Chapter 8 and 10 addresses the empirical findings, analysis and contribution for RQ2. Unit of analysis in this flow of research is product realization processes in manufacturing enterprises and describes the cross-functional challenges. Subsequently, chapter 3, 4 and 5 addresses the third sub-question RQ3 and defines the theoretical ground for the empirical sub-question RQ4. Chapter 9 and 11 addresses findings, analysis and contributions for RQ4. Unit of analysis in this flow of research is problem solving in product realization processes addressing the previous identified cross-functional challenges in product realization.

A short introduction precedes each of the following parts of the research. The short introduction provides the reader with a description of content and purpose of the part.

Part II Theory

This section's purpose is to clarify the theoretical ground behind improving product realization processes through examining related knowledge processes and organizational learning processes. The key message is that challenges in cross-functional work practices within product realization restrain organizational learning, which subsequently hinders problem-solving abilities in product realization processes. This project highlights differences in development practices, inefficient knowledge flows and misaligned coordination as three core challenges of cross-functional collaboration in product realization. To overcome these challenges, an organizational learning perspective on improving product realization provides theoretical explanations of learning processes, which integrate new organizational practices into the product realization process. Subsequently, I study literature on continuous improvement and innovation programs. Furthermore, the last part of the theory describes the theoretical ground for program design. There are four chapters in this theoretical part of the dissertation:

Chapter 2. Cross-functional work practices in product realization describes literature within operation management regarding product realization processes. The chapter defines central concepts and describes product realization characteristics from a systems perspective. The purpose of the chapter is to provide a theoretical answer to the first sub-question (RQ1: What characterizes cross-functional work practices in product realization?). Furthermore, the chapter provides a description of challenges in product realization processes, which are highlighted in the operation management literature.

Chapter 3. Knowledge processes in product realization describes literature within knowledge management in relation to product realization processes. The chapter provides categories of knowledge processes, describes frameworks relating knowledge processes to product realization and summarizes identified challenges related to knowledge processes in product realization.

Chapter 4. An organizational learning perspective on integration of new work practices describes organizational learning processes in product realization renewal. The purpose is to identify activities that facilitate integration of new organizational practices in product realization and herewith provide an answer for the third research question (RQ3: What activities facilitate organizational learning processes in product realization?). The identified activities directs the development of a CII-program as well as analysis of the organizational learning processes in the CII-program.

Chapter 5. Continuous improvement and innovation programs describes the theoretical ground for developing a continuous improvement and innovation (CII) program. The development process chosen for this project applies a probe-and-learn process where prototypes of the CII-program provides early learnings and user experiences for further development. Furthermore, the chapter defines continuous improvement and innovation associated with product realization and presents research on continuous improvement and innovation programs.

2 Cross-functional work practices in product realization

This chapter introduces existing research regarding product realization processes and discusses cross-functional challenges in developing products and production processes. In this project, I positioned myself in the production system that integrates new products and production processes into the existing production systems. I study the work practices in product realization comprising product development, process development and production as part of a product lifecycle. This is my answer to the first sub-question:

RQ1: What characterizes cross-functional work practices in product realization?

Firstly, I define product realization from a product lifecycle perspective. Secondly, I use a systems perspective of product realization to describe characteristics of cross-functional work processes in product realization. The systems perspective highlights an organizational divide between product development and production systems that product realization processes need to include in order to convert product concepts into physical products. Thirdly, I present challenges in product realization processes that a systems perspective highlights.

2.1 Defining product realization

The premise for this project is that product realization is a core process in manufacturing enterprises, where mutual functions contribute to transforming ideas into finished products available to customers. Manufacturing enterprises develop products through a cross-functional process of strategizing, researching, developing, manufacturing, selling and distributing value to customers who then use the product (Bellgran & Säfsten 2010). A product lifecycle perspective comprises activities throughout the entire process of turning customer needs into products available on the market (Bellgran & Säfsten 2010). Furthermore, a product lifecycle perspective also considers reuse of products and production equipment they are no longer required by the customer and production (Bellgran & Säfsten 2010). Stark (2016) presents product lifecycle management as managing products from idea to disposal.

Product lifecycle management or comprehensive product realization "… is a holistic approach to sustainable product development from market analysis, concept definition, design and analysis, production, customer service, all the way to the product's recycle" (Tomovic & Wang 2009). Product and process innovation span the product lifecycle, from setting strategic goals to customers' use of the product (Bellgran & Säfsten 2010). Figure 1 illustrates product realization as part of the product lifecycle.

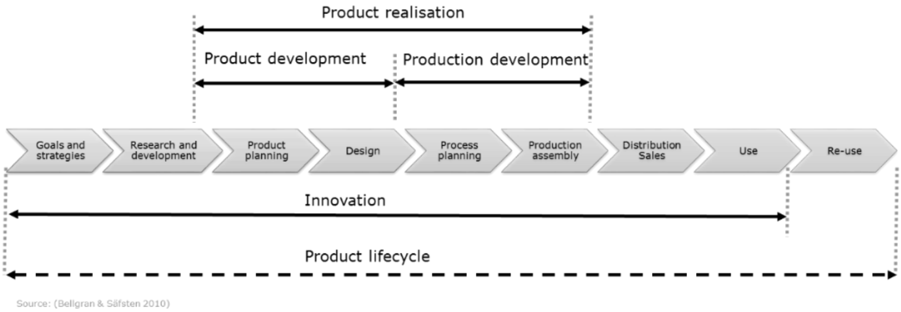


Figure 1. Product realization comprises product development and production development (adapted from Bellgran & Säfsten 2010). The innovation process implies aligning with strategies and objectives and enabling R&D before product realization, distribution, sales and use of the finished product. A product lifecycle additionally comprises re-use of the products and production processes (Bellgran & Säfsten 2010).

Product realization comprises both product development and the subsequent production development (Bellgran & Säfsten 2010). Similarly, Lu and Botha (2006) define product realization as a process of product design, process design, and process execution and improvement. In product development, designers plan which products to develop, design products and specify products to production development (Bellgran & Säfsten 2010). Product development drives improvement of product properties and performance (Lu & Botha 2006). In production development, engineers turn product specifications into appropriate production processes for parts and assembly (Bellgran & Säfsten 2010). Process development comprises development of technical knowledge, organizational capabilities and operational processes for products (Lu & Botha 2006). According to Stark (2016), a generic product lifecycle has five phases: imagine, define, realize, support/use and retire/dispose. Clark and Fujimoto (1991) argue that product and process development is a system of interconnected problem-solving cycles that includes functional design, drafting, prototype construction, testing, design review, drawing release, design change, process design, tool making, pilot run and manufacturing sign-offs. Research occasionally uses the notion "extended value stream" to include the impact of different product characteristics (Schönemann et al. 2014), other researchers use the term "value stream" to describe the value-creating process of product and process development (Morgan & Liker 2006; Lindlöf et al. 2013).

Research that focuses on developing products in a lifecycle perspective recognizes the importance of cross-functional processes (Stark 2016). According to Stark (2016), product lifecycle management is the only approach that manages products across the entire lifecycle. However, limited research examines the development of product realization as cross-functional processes (Lu & Botha 2006; Bellgran & Säfsten 2010). Less research focuses on the development of production systems compared to the development of products (Bellgran & Säfsten 2010). Furthermore, process development is only mentioned as a part of the product development process (Lu & Botha 2006; Dekkers et al. 2013).

This project focuses on problem solving in product realization processes in manufacturing enterprises and perceives product development and production development as interrelated and dependent processes. Innovation here relates to new as well as revised products, production processes and organizational practices within product realization. In the following section, I describe product development and production development as elements of product realization processes. Even though production is part of production development (Bellgran & Säfsten 2010), production is described separately to distinguish between development processes and production processes.

Product development

Product development is commonly conceptualized as transforming new product and service ideas into designs and specifications for production (Roozenburg & Eekels 1995; Ulrich & Eppinger 2012; Bellgran & Säfsten 2010). It is a process that includes steps or phases of planning, conceptualizing, designing, testing, refining and ramping up for production (e.g., Roozenburg & Eekels 1995; Tidd & Bessant 2013; Ulrich & Eppinger 2012; Bellgran & Säfsten 2010). As such, product development is part of product realization (Bellgran & Säfsten 2010), new business development

(Roozenburg & Eekels 1995) and innovation processes that encompass activities preceding adoption of new products on markets (Roozenburg & Eekels 1995; Bellgran & Säfsten 2010).

Scholars and practitioners take different approaches to product development (Bellgran & Säfsten 2010; Ulrich & Eppinger 2012). Bellgran and Säfsten (2010) describe three different approaches to product and production development:

> “1. The traditional approach, also called over-the-wall engineering, which refers to a minimum of cooperation and integration between the processes. Product development and production system development are separate processes and are carried out sequentially.
> 2. The parallel and iterative approach, where production is involved during the early phases of the product development process. The processes are not fully integrated despite a certain level of cooperation.
> 3. When the concurrent engineering approach is used the processes are integrated and characterised by close cooperation, team work and support from computerised communication networks. Focus is on time-to-market, the time for the market introduction” (Bellgran & Säfsten 2010).

Even though product development processes follow sequential processes, scholars and practitioners agree that mutual iterations are necessary, as product specifications develop during process development, testing and ramping-up products (Bellgran & Säfsten 2010). For example, product designers’ expectations regarding how material for a product part should behave in a process (e.g., injection molding) might be unfulfilled, as the product part goes into production even though product designers test and make prototypes in previous phases (Bellgran & Säfsten 2010). To overcome excess iterations, development processes can take a spiral shape (Ulrich & Eppinger 2012; Roozenburg & Eekels 1995; Bellgran & Säfsten 2010), or even more complex system processes with mutual development processes can deliver sub-systems to a larger product or process development (Ulrich & Eppinger 2012). Bellgran and Säfsten (2010) describe design processes as sequential or iterative, as illustrated in Figure 2, and they also refer to a concurrent engineering approach to design processes (Bellgran & Säfsten 2010).

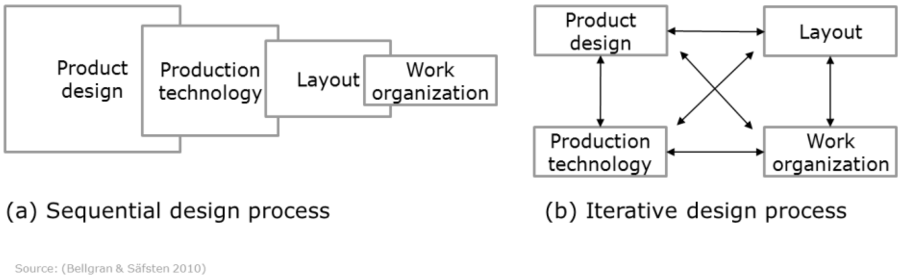


Figure 2. Sequential (a) and iterative (b) design processes (Bellgran & Säfsten 2010)..

Concurrent engineering is a method for developing products in parallel with developing production processes (Liker et al. 1996; Bellgran & Säfsten 2010). Liker et al. (1996) suggest that designers approach design problems, reason about and communicate design ideas and solutions in two different ways: (a) a traditional point-based design and (b) a set-based design, as illustrated in Figure 3. Liker et al. (1996) define point-based and set-based concurrent engineering as follows:

a) Point-based concurrent engineering design process: "… begins by defining the problem, then generating many alternative solutions. After preliminary analysis, engineers select the alternative with the most promise, then analyse, evaluate, and modify it until a satisfactory solution emerge. If the alternative proves infeasible, then designers select another alternative and/or revise the problem definition, and begin the process again. The key point is that a single solution is synthesized first, then analysed and changed accordingly – thus our term "point-based design"
b) Set-based concurrent engineering design process: "… begins with problem definition and idea generation. But rather than choosing an early winner, the designers gradually reduce the set of possibilities. The set of possibilities might include a number of discrete designs or a range of parameter values. They eliminate infeasible and clearly inferior alternatives with information currently available, then gather additional information in remaining alternatives. Information can be gathered through further development and analysis, from other functional areas, and through research. Then more alternatives are eliminated on the final solution"
(Liker et al. 1996, p. 167)

In a point-based approach, a designer selects a solution to a specific design problem and pursues this option until it fails or succeeds. In a set-based approach, a designer simultaneously pursues several options to a design problem and conducts experiments to verify which option is the best fit to a problem (Liker et al. 1996).

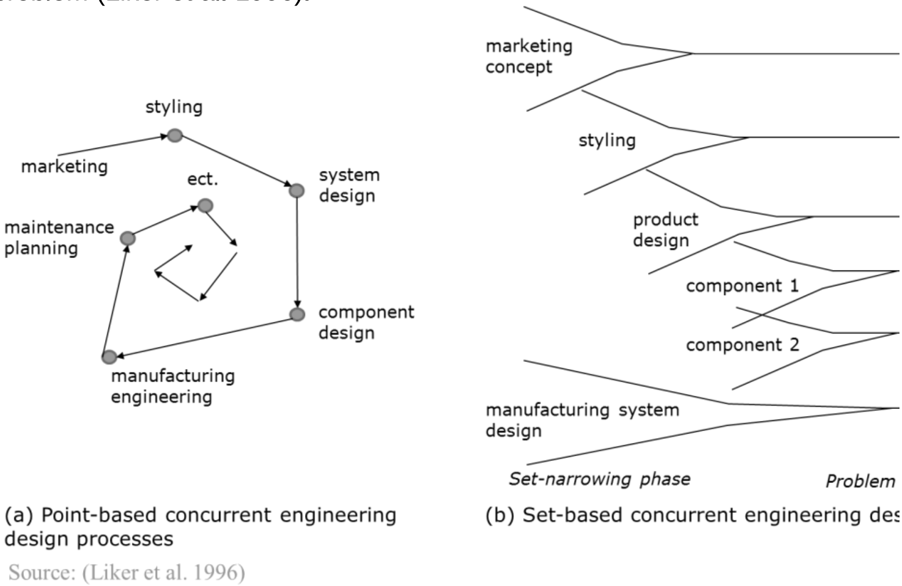


Figure 3. Two approaches to concurrent engineering design: (a) a point-based concurrent engineering design processes and (b) a set-based concurrent engineering design processes (Liker et al. 1996).

Concurrent engineering, simultaneous engineering and integrated product development share similarities, as they all seek to reduce development lead-time by developing parts of the product in parallel and by overlapping processes (Bellgran & Säfsten 2010; Dekkers et al. 2013; Liker et al. 1996). Studies show that concurrent engineering positively impacts product quality (Liker et al. 1996; Dekkers et al. 2013) and product costs (Liker et al. 1996).

Bellgran and Säfsten (2010) suggest that a majority of production costs can be determined by providing product development designers with as much information as possible about manufacturability in production in early stages of product development. In addition, investing in processes and overlapping development of products and processes can positively influence manufacturing costs and development speed (Lu & Botha 2006). Studies also show that benefits are derived from involving production development and engineering functions (Bellgran & Säfsten 2010) as well as from involving production employees (Jensen et al. 2016) in early stages of product development. Integrated product development describes integration between three parallel flows: markets, product and production processes, as shown in Figure 4. However, three parallel flows of development processes require a continuous transfer of information, a high degree of coordination and synchronization between the flows (Bellgran & Säfsten 2010; Ulrich & Eppinger 2012).

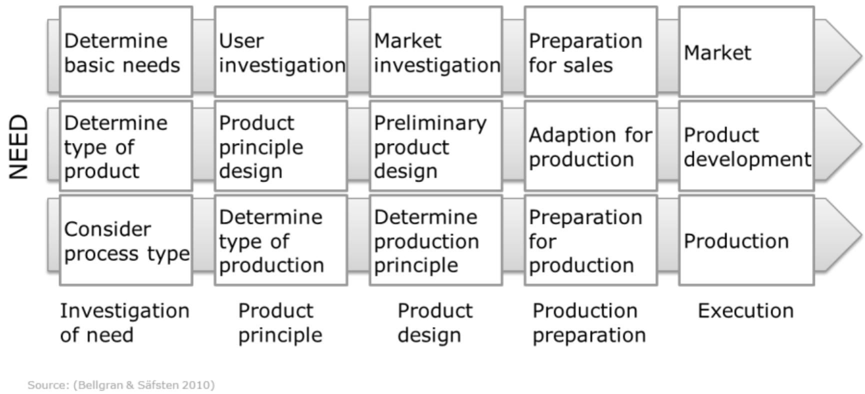


Figure 4. Integrated product development where market, products and production are developed in parallel flows (Bellgran & Säfsten 2010).

Some scholars (e.g., Ulrich & Eppinger 2012) suggest product development that includes design for manufacturing and prototyping as a way to integrate knowledge from production in product development. Design for manufacturing addresses manufacturing costs and product quality by utilizing diverse types of information throughout the development process (Ulrich & Eppinger 2012). According to Ulrich and Eppinger (2012), designers prototype product concepts, engineers prototype production designs and software developers prototype programs all in order to gain feedback from customers or other internal organizational members on an early stage of development.

In summary, product development applies design processes with successive steps of simultaneously experimentation to close knowledge gaps. This means that different development functions (e.g., product and production process development) learn through experimentation, which influences final product and process design. Design processes thus drive product and process specifications toward the customer. In addition, product development seeks to integrate knowledge influencing product and process specifications from different parts of the product lifecycle in order to reduce costs and time-to-market. The actual costs and time-to-market measure the output of the design process and provide knowledge for future product development. Both experimentation and integration imply cross-functional collaboration and knowledge sharing in different stages of product realization. However, knowledge can be scarce, ambiguous and abstract in early stages. Organizational members can therefore have difficulties in developing a shared understanding of ideas shaping a new product or production process. Prototyping is one method that can facilitate experimentation and integration in product realization.

Production development

Production development designs and specifies how to manufacture a product on a conceptual and tangible technological level (Bellgran & Säfsten 2010; Dekkers et al. 2013; Lu & Botha 2006). Developing a production system for a product comprises management and control, preparatory design, design specification, realization and planning and start-up (Bellgran & Säfsten 2010). Management and control involves planning the development process and allocating resources to the project (Bellgran & Säfsten 2010). The preparatory design includes background studies and pre-studies of the product and existing production system to form requirement specifications (Bellgran & Säfsten 2010). With these prerequisites in place, engineering starts developing design specifications for the production system (Bellgran & Säfsten 2010). Important considerations when developing a production system include choice of process, layout, technological level, material supply, workplace design and work-environment considerations (Bellgran & Säfsten 2010). As these choices are made, realization and planning comprise building the production system and planning the start-up (Bellgran & Säfsten 2010), followed by initiation of the actual start-up and an evaluation of the entire production system development project (Bellgran & Säfsten 2010). Production development as described by Bellgran and Säfsten (2010) intends to achieve Make to Stock production, although the steps for other types of production comprise similar elements.

Mutual alternative solutions and wishes for a production system are gradually evaluated and eliminated in order to decide on a best solution (Bellgran &

Säfsten 2010). The design process for production development is iterative similar to product development, even though they are described as linear (Bellgran & Säfsten 2010). Developing a process design comprises a series of design-build-test cycles (Clark & Fujimoto 1991; Lu & Botha 2006). According to Lu and Botha (2006), process execution is the implementation of processes in production and occurs simultaneously with pilot runs of the product during ramp-up. As such, production development comprises experimentation in which e.g., pre-series of prototypes can be helpful in the process of new processes start-up (Bellgran & Säfsten 2010). Lu and Botha (2006) describe process experimentation as a learning enabler in product realization. The locus experimentation matches type learning and learning mode to the stage of knowledge about the production process, as illustrated in Figure 5 (Lu & Botha 2006).

Locus of experimentation	**Learning via experimentation**	**Learning mode**	**Stages of process knowledge**
Full scale commercial Factory	Exploratory	By doing	Low
Pilot plant located as production site			
Pilot plat located at development site			
Laboratory			
Computer-aided simulation			
Theory, algorithms, heuristics	Hypothesis testing	Before doing	High

Source: (Lu & Botha 2006)

Figure 5. Locus of experimentation and learning modes (Lu & Botha 2006).

Production development also comprises improving the existing production system on mutual levels (Bellgran & Säfsten 2010). Improving production processes occurs simultaneously with process execution through problem solving (Lu & Botha 2006), which can bring problems concerning product quality or equipment performance (Bellgran & Säfsten 2010; Lu & Botha 2006). As such, production development supports product realization processes in e.g., improving product and process quality as well as reducing costs and time-to-market (Lu & Botha 2006).

Lu and Botha (2006) suggest that manufacturing enterprises that learn from earlier process development can benefit by reducing manufacturing costs and increasing process developing capabilities, and they provide a framework describing intra-functional, inter-functional and learning enablers that influence product realization processes (Lu & Botha 2006). Learning from previous development projects requires some form of feedback (Fundin & Elg 2010; Lu & Botha 2006) or lessons learned (Chirumalla 2017). Other scholars claim that product lifecycle management provides methods that serve the purpose of reducing time-to-market and costs through knowledge reuse and effective feedback mechanisms (Tomovic & Wang 2009; Stark 2016). However, the literature often ignores how product designers can support process engineers in developing test processes (Lu & Botha 2006).

Some scholars suggest that separating research and advanced engineering from development processes enables more innovative solutions (Dekkers et al. 2013). However, organizational separation of development processes can restrain alignment across functions. Several scholars (Pisano & Wheelwright 1995; Adler et al. 1999; Lu & Botha 2006; Stark 2016) point out that throwing product specifications over the wall to process engineering or even with production squeeze out time for subsequent development time. Instead, scholars suggest overlapping activities and channels of communication (Clark & Fujimoto 1991; Lu & Botha 2006).

In summary, production development is a process that includes both experimentation and solving practical problems in order to implement products and processes in production. The objectives are conflicting to some extent, as they both aim to improve quality and reduce costs on one hand while reducing time-to-market on the other. Process development shares processes with product development and simultaneously confronts reality in production. Production development is concurrent and includes overlapping activities with both product development and production. The production development processes evolve through experimentation and, more specifically, through problem solving in production.

Production

The next step in product realization processes is production and assembly, as illustrated in Figure 1 (Bellgran & Säfsten 2010). However, scholars use the concepts “production” and “manufacturing” interchangeably when distinguishing organizational levels. Therefore, I first describe definitions of production and manufacturing from the operation management literature, and then I define order-decoupling points that mark the shift between development processes and production processes in manufacturing enterprises.

3. Key concepts defining production, manufacturing and related processes.

Concept	Definition	Categorizations and dimensions	References
Production	"Production is the result or output of industrial work in different fields of activity"	"… e.g. agricultural production, oil production, energy production, manufacturing production."	(CIRP 1990, p. 736)
Manufacturing production	"Manufacturing production (usually abbreviated to 'production' when used within the context of manufacturing activities) is the act or process (or the connected series of acts or processes) of actually physically making a product from its material constituents, as distinct from designing the product, planning and controlling its production, assuring its.quality."		(CIRP 1990, p. 736)
Manufacturing	"Manufacturing can be defined as the application of physical and chemical processes to alter the geometry, properties, and/or appearance of a given starting material to make parts or products; manufacturing also includes the joining of multiple parts to make assembled products."	"The processes that accomplish manufacturing involve a combination of machinery, tools, power, and manual labor."	(Groover 2008, p. 23)
Process	"A systematic sequence of operations to produce a specific result."		(CIRP 1990, p. 741)
Process	"A process is a repetitive network within a certain order of linked activities using information and resources to transform 'object in' to 'object out', from identification to satisfaction of customer needs."		(Bellgran & Säfsten 2010, p. 114)

Table 3 (continued)			
Process	“Any activity or group of activities that takes an input, adds value to it, and provides an output to an internal or external customer. Processes use an organization’s resources to provide definitive results.”	Production process: “Any given process that comes into physical contact with the hardware or software that will be delivered to an external customer, up to the point the product is packaged (e.g., manufacturing computers, food preparation for mass customer consumption, oil refinement, changing iron ore into steel). It does not include the shipping and distribution process.” Business process: “All service processes and processes that support production processes (e.g., order process, engineering change process, payroll process, manufacturing process design). A business process consists of a group of logically related tasks that use the resources of the organization to provide defined results in support of the organization’s objectives.”	(Harrington 1991, p. 9)

The International Academy for Production Engineering CIRP (1990) uses “production” on a high level to describe the type industry and uses “manufacturing production” to describe the act or process of altering materials into products. CIRP (1990) define “manufacturing production” as “… distinct from designing the product, planning and controlling its production, assuring it quality.” The production or manufacturing process is a sequence (CIRP 1990) or network of activities that transforms an object (Bellgran & Säfsten 2010) and is in physical contact with hardware or software delivered to customers (Harrington 1991). Table 3 lists key concepts defining production, manufacturing and related processes.

In this study, I apply the definition of production as short for manufacturing production to describe the processes physically making a product (CIRP 1990). In addition, I apply the definition of processes as repetitive networks of activities transforming an object in to an object out (Bellgran & Säfsten 2010). A development process is then the design and specification of products and production processes, and production is the physical transformation of materials into physical products.

The order decoupling point describes the point at which customers' orders decouple production processes and is interesting in relation to product realization, as it describes the degree to which development processes design products or specify orders to a specific customer. As such, the order decoupling point disengages development processes from production (Bellgran & Säfsten 2010; Hill 2000). Table 4 lists two definitions of order decoupling points (Bellgran & Säfsten 2010; Hill 2000).

4. Two definitions of customer order decoupling points.		
Parameter	**Definition**	**Reference**
Customer order decoupling point (CODP)	"The customer order decoupling point (CODP) splits the flow and decides where the planning point will be. Up- stream CODP production is carried out on forecast, downstream on customer order. This means that we get the following main categories of production control; Engineer To Order (ETO), Make To Order (MTO), Assembly To Order (ATO), and Make To Stock (MTS)"	(Bellgran & Säfsten 2010, p. 61)
Alternative responses to markets and their lead-time implications	In order from long lead times to short lead times: "1. *Design to order* – new product response where companies design and manufacture a product to meet the specific needs of a customer. 2. *Engineer to order* – changes to standard products are offered to customers and only made to order. Lead times include the relevant elements of engineering design and all manufacturing. 3. *Make to order* – concerns manufacturing a standard product (any customization is nominal and does not increase total lead times) only on receipt of a customer order or against an agreed schedule or call-off. 4. *Assemble to order* – components and subassemblies have been made to stock. On receipt of an order (or against an agreed schedule or call-off), the required parts are drawn from work-in-progress/component inventory and assembled to order. 5. *Make to stock* – finished goods are made ahead of demand in line with sales forecasts. Customers' orders are met from inventory."	(Hill 2000, p. 66)

Figure 6 illustrates the point at which customers demand require product specification following classification in Bellgran and Säfsten (2010).

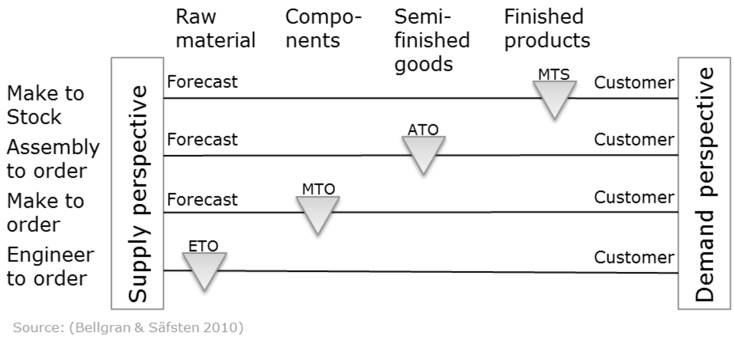


Figure 6. Order decoupling point in Bellgran and Säfsten (2010, p. 62), illustrating the point at which customers demand require product specification.

In Make to Stock, all products and variants are manufactured prior to a customer's order, which is typical for mass-production. Products and production processes are highly standardized to deliver stable and reliable products to customers. Product development processes follow their own rhythm of repetition connected to production development apart from continuous improvement. Manufacturing enterprises offering Assembly to Order or Make to Order products customize semi-finished goods, modules or components to customers' orders. Mass-customization business models often focus on this level, where product development designs parts, modules or components independently and ensures valid combinations. Product development repeats development processes frequently with subsequently reduced product development lead-time. Manufacturing enterprises that offer Engineer to Order products (or solutions) specify every order to a specific customer. Delivery times for Engineer to Order products are therefore longer than for Make to Stock products. Nevertheless, Engineer to Order products also have shorter development lead-time than for Make to Stock products. In Engineer to Order processes, an engineer designs a product to customer specifications and develops a new way of meeting these specifications based on previous projects. As such, product development is often part of an Engineer to Order process, resulting in less transparency of lead-time in product development (Hill 2000; Bellgran & Säfsten 2010; Dekkers et al. 2013).

Both products and production processes are continuously improved after implementation in production and throughout the product lifecycle (Bellgran & Säfsten 2010). A predominant paradigm within continuous improvement is lean thinking (Womack 2003). Toyota stood out as having an exceptional efficient production system in research comparing the world’s automotive industry (Womack et al. 2007). Lean thinking has then been described based on Toyota’s production system (Womack 2003; Hines et al. 2004; Holweg 2007; Pil & Fujimoto 2007; Liker & Convis 2012) and product development system (Liker et al. 1996; Liker 2011; Ward & Sobek 2014). At Toyota, continuous improvement involves employees and is based on the assumption that all workers are knowledge workers who understand the value-stream process and create improvements on a daily basis (Womack 2003; Liker & Convis 2012). Lean thinking focuses on creating value for customers and makes the value flow in a stable stream (Womack 2003). A stable value stream implies eliminating disturbances such as wasteful activities or resources that do not create value for customers (“muda”), overburdening workers (“muri”) and equipment and unevenness (“mura”) (Womack 2003; Bicheno et al. 2009). Value streams achieve stability when materials flow to work processes Just-in-time to meet customers’ demand (Womack 2003).

In summary, production is a transformation process that turns materials and specifications into physical products using production processes in manufacturing enterprises. The order decoupling point refers to the point at which products are specified to customers’ orders and describes when development processes transition to production. Products and processes are further developed continuously as a part of daily work.

2.2 A systems perspective

In the following section, I consider a systems perspective of product realization in order to understand product realization processes as a part of product development and production systems. A systems perspective highlights an organizational divide between systems of product development and production. Most of the literature treats product development separately from production/process development and production (Lu & Botha 2006; Dekkers et al. 2013). However, from a product lifecycle perspective, the product realization process spans both development processes and production, as shown in Figure 1.

Organizations as systems

From an open systems perspective, an organization is “open” and interacts with its surrounding environment (Morgan 1997; Bellgran & Säfsten 2010), which thus directs attention toward understanding an organization's primary task as defined by the organization's members (Morgan 1997). An organization consists of sub-systems that are wholes within wholes, which means that sub-systems are defined as systems within systems (Morgan 1997). Scholars study inter- and intra-organizational relations and describe central business processes and alignment within and between sub-systems (Morgan 1997). Open systems are characterized as being goal-seeking, hierarchical, holistic and equifinality-seeking (Bellgran & Säfsten 2010). Describing an organizational system as an open system enables scholars to imply that organizations are able to learn from experience and from adapting new knowledge from outside the organization (Morgan 1997; Argyris 2008; Schein 2010; Bellgran & Säfsten 2010). In addition, scholars describe organizations as work systems where technical and social systems are interdependent (Klein 1994). Sociotechnical organizational design links with industrial democracy and assumes that designing organizations implies active choices influenced by values (Klein 1994).

Scholars describe product development and production systems as open systems and sociotechnical systems (Liker & Majchrzak 1994; Morgan & Liker 2006; Bellgran & Säfsten 2010).

Defining production systems

When defining a "manufacturing system," CIRP (1990) include sales, design, production and shipping functions. Groover (2008) however defines a "manufacturing system" at a factory level, where Bellgran and Säfsten (2010) use the term "production system." Groover (2008) uses the term "production system" as "a collection of people, equipment, and procedures organized to perform the manufacturing operations of a company (or other organization)" and places manufacturing support systems (e.g., logistics, technical support, quality, product design) at an enterprise level within the production system. Table 5 lists key concepts in defining manufacturing and production systems.

5. Key concepts in defining manufacturing and production systems.			
Concept	**Definition**	**Categorizations and dimensions**	**References**
Manufacturing system	"A manufacturing system is an organization in the manufacturing industry for the creation of manufacturing production, or, simply, production. In the mechanical and electrical engineering industries, a manufacturing system, in general, has an integrated group of functions: e.g. the sales, design, production and shipping functions. A research function may provide a service to one or more of the other functions."		(CIRP 1990, p. 736)
Manufacturing system	"Manufacturing systems can be individual work cells, consisting of a single production machine and worker assigned to that machine."	Types of manufacturing systems: (a) manual work system, (b) worker-machine system, (c) automated system.	(Groover 2008, p. 4)
Production system	"In a production system raw material is transformed into a product."		(Bellgran & Säfsten 2010, p. 7)

Table 5 (continued)			
Production system	"A production system is a collection of people, equipment, and procedures organized to perform the manufacturing operations of a company (or other organization)."	two categories or levels: "1. Facilities. The facilities of the production system consist of the factory, the equipment in the factory, and the way the equipment is organized." (factory-level) "2. Manufacturing support systems. This is the set of procedures used by the company to manage production and to solve the technical and logistics problems encountered ordering materials, moving the work through the factory, and ensuring that products meet quality standards. Product design and certain business functions are included among the manufacturing support systems." (enterprise-level)	(Groover 2008, p. 3-4)

For the empirical context in this project, I use the term "production system" to refer to the organizational system enabling value creation for an enterprise's customers (Groover 2008). Production systems comprise manufacturing systems and manufacturing support systems (Groover 2008). In manufacturing systems, production processes transform materials and resources into products or services through e.g., cutting, bending, welding, painting and assembling (Harrington 1991). Even though service becomes more and more integrated in products, I only consider production systems with physical products.

Within manufacturing support systems, business processes such as purchasing, planning, engineering, IT and maintenance support the manufacturing system (Groover 2008; Harrington 1991). To Groover (2008), the product design is part of the production system, while Bellgran and Säfsten (2010) are more explicit and define product design as part of a product realization process. As such, the production system is a transformation system that converts inputs in initial stages into intended output for customers (Bellgran & Säfsten 2010). Subsystems such as a human system, technical system, information system, and management and goal system aids processes within the transformation system (Bellgran & Säfsten 2010).

Defining product development systems

The product development system is an input/output transformation system that has sub-systems that correspond to production systems. Describing production as systems is commonplace within operation management literature, where “production system” or “manufacturing system” are mentioned in 8230 English journal papers since 2000. In contrast, a similar search for “product development system” or “product and process development system” revealed only 76 English journal papers, 17 of which mention “lean” or “Toyota” while 54 relate to IT, data management or computer aided design.

Furthermore, I have not found literature that describes how product development and production systems work together in practice across system boundaries. Product development and production systems might formulate different purposes, even though they share a primary task (product realization) that relates to the company’s business model and mission statement. In this study, I base my understanding of product development systems on the definitions of systems and systems design as proposed by Harrington (1991) and CIRP (1990) as well as on the definition of product and production development provided by Bellgran and Säfsten (2010).

2.3 The product realization system

Leonard-Barton (1992) suggested that perceiving product development projects as self-contained units of analysis directs attention toward managing the interface between projects and organization. A systems perspective of product realization assumes that product development, production development and production are interdependent subsystems within a manufacturing system. I use Galbraith’s Star Model (Galbraith et al. 2002) to describe production systems, as it links entities in the system to a company’s strategic purpose and provides output in terms of performance and behavior. The Star Model emphasizes the importance of treating management alignment as a continuous process (Galbraith et al. 2002). Management develops the structure, process, people and reward as well as the interdependencies (see Figure 7) that enable the desired behavior and performance according to strategic objectives (Galbraith et al. 2002).

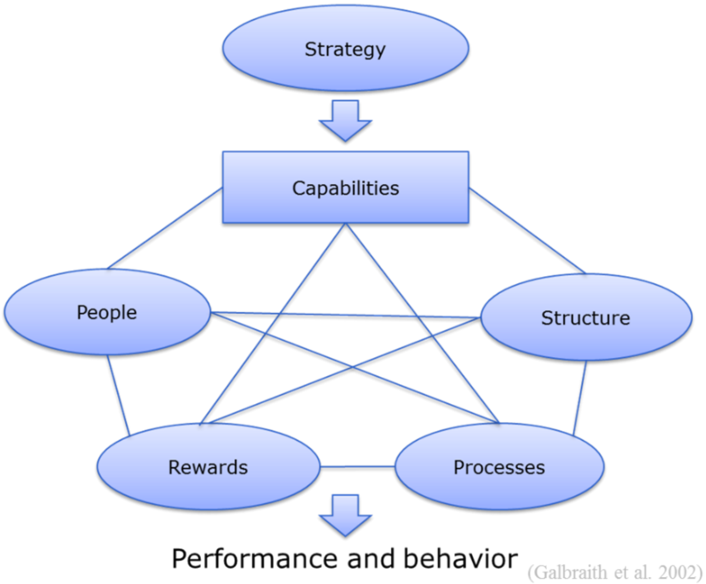


Figure 7. The Star Model visualizes interdependencies of capabilities, structure, processes, people and rewards in designing an organization with a strategic intention to achieve performance and behavior (Galbraith et al., 2002).

An organization's capability to achieve its strategic objectives is determined by management's continuous alignment of the structure, processes, people's skills and rewards (Galbraith et al. 2002). These entities and their interdependencies form the organizational design (Galbraith et al. 2002) in a system where equilibrium only exists in short periods of time, as changes in one entity lead to changes in the others.

The following characterization of the product realization system is based on a literature review described in Chapter 7.

Capabilities

Which capabilities then do product development, production development and production have in common? The product realization system has a shared objective of achieving a brief time-to-market cycle (Lu & Botha 2006; Saunders et al. 2014) or product development cycle time (Nagaraj 2004; Yasumoto & Fujimoto 2005; Saunders et al. 2014). Both time-to-market and product development cycle times include the time it takes to complete activities in the product realization process.

Structures

One overall emphasized element is cross-functional integration (Nagaraj 2004; Yasumoto & Fujimoto 2005; Lu & Botha 2006; Valle & Vázquez-Bustelo 2009; Vroom & Olieman 2011; Saunders et al. 2014). Cross-functional teams, however, primarily include engineering specialists within product and production development (Nagaraj 2004; Lu & Botha 2006; Rauniar et al. 2008) and matrix organizational structure (Saunders et al. 2014). The purpose of integration is to provide a formal structure for sharing knowledge (Carlile 2004; Rauniar et al. 2008; Vroom & Olieman 2011), to develop a shared meaning and negotiation of common interests (Carlile 2004) as well as inter-department collaboration (Kahn 2005), communication and conflict resolution (Lu & Botha 2006) across organizational boundaries. In addition, early involvement of organizational members in product realization can allow them to provide feedback regarding product and process development (Nagaraj 2004; Rauniar et al. 2008; Valle & Vázquez-Bustelo 2009). Formal knowledge sharing is supported by IT systems (Valle & Vázquez-Bustelo 2009; Vroom & Olieman 2011), and informal knowledge sharing involves designers asking their colleagues (Vroom & Olieman 2011). Knowledge is also retained in modular designs of products and processes (Lu & Botha 2006; Saunders et al. 2014). Furthermore, cross-functional integration also implies the use of multidisciplinary problem-solving in teams (Nagaraj 2004) to enable exploratory knowledge creation (Yasumoto & Fujimoto 2005).

Processes

Concurrent engineering and integrated product development imply parallel work processes with overlapping activities and reviews (Nagaraj 2004; Valle & Vázquez-Bustelo 2009) or signoffs (Saunders et al. 2014). Sharing, accessing, transferring and managing knowledge is integrated into the work processes (Carlile 2004; Rauniar et al. 2008). Knowledge interaction also implies exploration and experimentation in order to learn and also implies front-loading development processes with optional solutions (Yasumoto & Fujimoto 2005; Lu & Botha 2006). Prototyping is a method of involving organizational members across functions to learn through experimentation (Nagaraj 2004).

People

Technical designers, with their specialized expertise and competencies, play a vital role in the product realization system (Nagaraj 2004; Vroom & Olieman 2011; Saunders et al. 2014). However, teamwork and collaboration across the different types of expertise is also vital (Valle & Vázquez-Bustelo 2009). Yasumoto and Fujimoto (2005) additionally emphasize the role of heavy weight project managers to manage the development of engineering skills as well as facilitate teamwork and cross-functional collaboration among organizational members.

Rewards

Lu and Botha (2006) identify five objectives in product realization: product and process quality, smooth and fast ramp-up, cost performance, fast product realization and sustainable competitiveness. These objectives can result in conflicting goals for organizational members in product realization (Lu & Botha 2006). Rauniar et al. (2008) emphasize that efficient knowledge processes can reduce product development glitches, while Valle and Vázquez-Bustelo (2009) draw attention to the importance of motivating teamwork and early involvement of organizational members in product realization activities.

2.4 Challenges in the product realization system

This section describes the challenges identified when applying a systems perspective on product realization and the relationship between production and product development systems. This section also seeks to answer RQ1: What characterizes cross-functional work practices in product realization?

Workflow and structures

One prevailing topic in the literature is cross-functional integration and involvement in early stages of product realization. Both cross-functional integration and early involvement are crucial to enabling knowledge sharing and feedback when workflows are parallel. Parallel workflows reduce product realization lead-time. Knowledge about products and product realization is systemized, modularized and standardized to enable its reuse, which allows problem solving in product realization processes to become a cross-functional and multidisciplinary issue requiring multi-level coordination in hierarchical organizations. Nagaraj (2004) suggests that organizations utilize multidisciplinary problem-solving teams.

Concepts such as concurrent engineering, integrated product development and lean product and process development all emphasize cross-functional integration, early involvement, parallel workflows and multi-level systemization. The purpose of concurrent engineering and integrated product development are to prevent “throwing it over the wall” work practices (Lu & Botha 2006; Valle & Vázquez-Bustelo 2009). However, concurrent engineering depends on competition and technology concept (Valle & Vázquez-Bustelo 2009). Even though there is a high degree of mutual inter-dependence, concurrent engineering can include hidden costs in in situations with radical new technology, high complexity and dynamic environmental conditions (Valle & Vázquez-Bustelo 2009). Yasumoto and Fujimoto (2005) study Japanese firms’ adaptive capabilities and suggest that firms adopt proper product development routines that are aligned with product attributes or industrial dynamism, which suggests a contingency perspective on product realization. Saunders et al. (2014) refer to Morgan and Liker (2006) in their description of lean product and process development. Morgan and Liker (2006) described Toyota’s product development system. Table 6 summarize the characteristics and challenges for workflow and structures.

6. Characteristics related to workflow and structures subsequently challenging cross-functional work practices in product realization.

Characteristics	Challenges
Parallel workflows	Cross-functional integration promote early involvement and prevent “throwing it over the wall” work practices
Mutual inter-dependence across functions	Multi-level systemization

Knowledge processes

Explicated knowledge concerns e.g., product specifications, process specifications, procedures and routines in formal IT-systems and through systemization of products. Vroom and Olieman (2011) argue that designers search for relevant knowledge in many places and ask colleagues in order to find solutions that can help them solve design problems. Tacit knowledge on the other hand can be accessed by teams and by involvement. However, as Carlile (2004) points out, it is not only a question of explicit versus tacit knowledge but also a question of managing knowledge boundaries.

A major key to accessing an organization's collective knowledge is to understand that tacit knowledge follows the individual organizational member taking part in product realization. Thus, scattered knowledge is less accessible for subsequent product realization projects or can even become lost if individuals leave the organization. Everybody taking part in product realization holds knowledge, including engineers, technicians, operators and production supervisors. Even though scholars such as Vroom and Olieman (2011) suggest developing IT-systems for knowledge sharing, they do not address the motivation for adding content to these systems. Carlile (2004) suggests that there are political interests involved in knowledge invested in practices. Table 7 summarize characteristics and challenges related to knowledge processes.

7. Characteristics related to knowledge processes subsequently challenging cross-functional work practices in product realization.

Characteristics	Challenges
Managing knowledge boundaries (novelty)	Develop shared understandings of knowledge describing products and processes.
Sharing knowledge across organizational boundaries	IT-systems can process explicit knowledge though dependent on investment in generating content. Reviews, teams and other types of involvement can process tacit knowledge however companies risk that knowledge remain individual.

Horizontal and vertical collaboration

Lu and Botha (2006) as well as Valle and Vázquez-Bustelo (2009) mention that aligning objectives enables collaboration across product realization processes. The interdependency in product realization processes spans organizational/functional boundaries. The different organizational functions represent specialized expertise, where organizational members invest their knowledge into competences and skills, thus making problem solving a multidisciplinary process in product realization. Nagaraj (2004) suggests that management's role in product realization includes participation in design reviews, distributing projects in calendars as well as prioritizing and allocating resources. However, what are the incentives for sharing knowledge and collaborating across functions?

Lu and Botha (2006) address learning enablers both in terms of learning modes and learning levels, which might be helpful when considering cross-functional problem solving in product realization processes. Kahn (2005) studies department status effects on product development performance and suggests that no one department should dominate product development. Furthermore, squeezing out development time can be a consequence of ambiguous or conflicting goals of product realization (Lu & Botha 2006). Scholars also suggest collaboration with external stakeholders; however, this characteristic is not included in the present study. Table 8 summarize characteristics and challenges for horizontal and vertical collaborations.

8. Characteristics related to horizontal and vertical collaboration subsequently challenging cross-functional work practices in product realization.

Characteristics	Challenges
Dependency on multidisciplinary collaboration	Collaborate in a climate with ambiguous or conflicting goals

In summary, this section identifies workflows and structures, knowledge processes and coordination. In practice, these three elements/factors are dependent on how the manufacturing enterprise is organized, on product and production complexity and the concepts (concurrent engineering, integrated product development, lean thinking) that are valued. These identified challenges are discussed in Chapter 12. Sources of these challenges are found in the two empirical cases, which are presented in Chapter 8 and analyzed in Chapter 10. In the following chapter, I take a further look at the knowledge processes.

3 Knowledge processes in product realization

Within knowledge management, the knowledge-based theory of the firm is developed based on the resource-based theory of the firm (Hislop 2013). The knowledge-based theory of the firm assumes that firm-specific knowledge is difficult to replicate and emphasizes that knowledge sharing and integration between people are key to achieving a competitive advantage (Hislop 2013).

This chapter describes literature within knowledge management in relation to product realization processes. The purpose is to provide categories of knowledge processes for discussion about insufficient knowledge processes in product realization. The chapter then describes frameworks that relate knowledge processes to product realization.

Scholars describe knowledge as being at the heart of a resource and as an acting catalyzer in product realization (Pitt & MacVaugh 2008). Applying an organization's existing knowledge (know what it knows), recombining it and identifying gaps in knowledge (know what it does not know) are crucial steps toward achieving organizational innovation capabilities (Lee & Kim 2001; Cohen & Levinthal 1990), especially in product development (Pitt & MacVaugh 2008). Organizational members in product realization share and transfer knowledge to allocate information, such as specifications and capabilities, to activities in the product realization process (Boer et al. 2001; Carlile 2004). In addition, organizational members acquire knowledge from outside the organization when they need knowledge that they do not have (Pitt & MacVaugh 2008). Besides new products and processes, product realization generates new knowledge related to the developed products and processes as well as the experience of the development process itself (Cacciatori et al. 2012). In this way, organizational members share, transfer, acquire, generate, create and store knowledge in relation to product realization (Costa & Monteiro 2016; Foss et al. 2010). Authors describe these activities as knowledge processes (Costa & Monteiro 2016; Xu et al. 2010; Nonaka 1994; Foss et al. 2010). Table 9 provides an overview of definitions and dimensions of knowledge processes.

9. Definitions and dimensions of key knowledge processes		
Concept	**Definition**	**References**
Knowledge creation	"the capability of a company as a whole to create new knowledge, disseminate it throughout the organisation, and embody it in products, services and systems"	(Nonaka and Takeuchi 1995 p. 3) in (Lindlöf et al. 2013)
Knowledge generation	"… as specific activities and initiatives undertaken by a company to increase their stock of corporate knowledge."	(Davenport & Prusak, 1998) in (Xu et al. 2010)
Knowledge production	"… as an achievement and codification of meaning through the communication of information"	(Machlup, 1962) in (Xu et al. 2010)
Knowledge sharing	" … the provision or receipt of task information, know how, and feedback on a product or a procedure (cf. Hansen, 1999)."	(Foss et al. 2010, p. 457-458)
Knowledge sharing	"the act of placing knowledge possessed by an individual at the disposition of others within the organization" (Camelo-Ordaz et al., 2011, p. 1444)	(Costa & Monteiro 2016)
Knowledge sharing	… is a dialog between individuals often mediated by an object.	(Nonaka 1994)
Knowledge transfer	"the process through which one unit (group, department or division) is affected by the experience of another"	(Argote & Ingram 2000, p. 151) in (Lindlöf et al. 2013)
Knowledge acquisition	"the process by which organisations obtain knowledge"	(Molina-Morales et al., 2014, p. 236) in (Costa & Monteiro 2016)
Organizational knowledge base	"… comprises a whole network of organizational knowledge	(Nonaka 1994)
Organizational knowledge	Artifacts, human beings and technologies	(Xu et al. 2010)
Knowledge codification	"… the inscription of knowledge into text, drawings, tem-plates, models and similar media"	(Cacciatori et al. 2012)

3.1 Three categories of knowledge processes

Xu et al. (2010) and Costa and Monteiro (2016) review literature on knowledge management processes' impact on product innovation. Costa and Monteiro (2016) identify knowledge creation and knowledge application as two central knowledge processes that are the most frequently studied. Xu et al. (2010) separate knowledge processes into three main categories: knowledge creation, knowledge usage and processing of knowledge. In the following section, I describe these three categories of knowledge processes.

Knowledge creation in product realization

Knowledge creation covers processes that create, generate or acquire knowledge. In an empirical study, Richtnér et al. (2014) find that increases in organizational slack influence knowledge creation positively in product development, and decreases in organizational slack disrupt knowledge creation and consequently compromise innovation. Tyagi et al. (2015) propose that the use of lean tools and methods promotes learning and knowledge creation in product development. Similar to knowledge creation, knowledge generation and production are related to activities that lead to emergence and codification of organizational knowledge (Xu et al. 2010). Bogers and Lhuillery (2011) state that firms rely on internal knowledge generation from activities in R&D, marketing and manufacturing functions and propose that these functions support absorption of external knowledge. Product realization as a development process inherently includes some degree of novelty which necessitates knowledge generation (Turner et al. 2014), as formulating possible solutions to an innovation problem generates knowledge (Benner & Tushman 2015). Pitt and MacVaugh (2008) suggest that internal knowledge creation practices should be balanced according to the costs of external knowledge acquisition.

Knowledge usage in product realization

The terms knowledge sharing, knowledge exchange and knowledge transfer are used interchangeably in the literature (Foss et al. 2010). Some scholars use knowledge transfer to express the output of a knowledge sharing process (Foss et al. 2010) and can represent e.g., agreements within or between organizations (Foss et al. 2010). Knowledge sharing is a relational process occurring among organizational members regarding practices (Hislop 2013) and involves making individual knowledge available to others within an organization (Costa & Monteiro 2016). Organizational members in product realization share knowledge that is relevant for developed products or processes as well as the development process itself. As such, knowledge sharing is an antecedent to knowledge creation (Foss et al. 2010; Cohen & Levinthal 1990). Knowledge transfer describes moving knowledge across internal and external organizational boundaries (Boer et al. 2001; Bellgran & Säfsten 2010; Lee & Kim 2001). Boer et al. (2001) describe five dimensions of knowledge transfer within continuous product innovation:

(1) The routes between functions, projects or products and phases in the product development process, (2) the level of dissemination between

individuals, groups and organizations, (3) the scope of knowledge or level of specialization, (4) the degree of abstraction and generalization and (5) the degree of articulation or embodiment (Boer et al. 2001).

Processing of knowledge in product realization

Product development projects contribute information such as product specification and documentation to an organization’s knowledgebase (Nonaka 1994). The knowledge regarding how to carry out product realization is partly stored as individual knowledge (e.g., skills and competencies) and partly as organizational knowledge (e.g., procedures and documentation). Nonaka (1994) perceives the knowledge base as the bottom layer of an organization, with business processes and project teams constituting two other layers. “Once the task of a team is completed, members move "down" to the knowledge-base layer at the bottom and make an "inventory" of the knowledge acquired and created in the project” (Nonaka 1994). An organization needs to apply organizational knowledge in order to realize the potential value achieved through knowledge creation (Xu et al. 2010). However, not all knowledge is stored or coded and retrieved from the knowledge base in future projects. Chirumalla (2017) suggests that insufficiently learned lessons limit the knowledge available for reuse in future products. Consequently, some of the knowledge generated in a product realization process can live on as individual knowledge that hampers access to knowledge in future product realization processes.

3.2 Frameworks for knowledge processes in product realization

In the following section, I present frameworks that describe knowledge processes related to product development or product realization.

Nonaka’s theory of knowledge creation dominates the literature in the field of knowledge management (Costa & Monteiro 2016; Foss et al. 2010; Gourlay 2006). Nonaka describes four types of mechanisms in the conversion of knowledge: socialization, externalization, combination and internalization (SECI-model), where a knowledge creation process cycles through the four mechanisms in a spiral (Nonaka 1994; Nonaka et al. 1994). Nonaka (1994) studies knowledge processes between individuals, between individuals and groups and between groups. Other scholars focus on cross-functional knowledge processes, such as Carlile (2004) who proposes a 3-T framework in which boundaries of knowledge novelty relate to transfer, translation and transformation processes. In addition, Lam (2000) proposes a framework that integrates learning activities at micro- and macro-levels. In addition, Lam (2000) argues that there is an interactive relationship between different types of knowledge and organizational forms.

Xu et al. (2010) propose that there are three sources of organizational knowledge for innovation: artefacts (physical objects), human beings (experience, skills and competencies) and technologies (methods and technologies producing artefacts). In addition, Xu et al. (2010) propose the use of a macro process in continuous innovation. The first pre-creation phase comprises extracting, acquiring and identifying internal or external knowledge. The second creation phase involves producing, creating and generating knowledge. In the third phase, the created organizational knowledge is then stored, personalized or codified for sharing and dissemination. The fourth usage phase comprises the utilization, use and application of the organizational knowledge. Finally, in the fifth phase organizational knowledge is evaluated, refined and integrated for post-usage. Even though the macro process is described as sequential, the described activities do not necessarily occur sequentially (Xu et al. 2010).

Lee and Kim (2001) suggest distinguishing between applying a technical approach to knowledge management that considers information systems as objects from applying a managerial approach that considers knowledge workers as objects. According to Lee and Kim (2001) however, knowledge management links organizational knowledge with knowledge management processes. Building on lifecycle theory, organizational capabilities grow through the four stages: initiation, propagation, integration and networking (Lee & Kim 2001). In the initiation stage, organizations recognize the importance of organizational knowledge and prepare knowledge management efforts (Lee & Kim 2001). In the propagation stage, organizations build infrastructures in order to motivate and facilitate knowledge creation or the acquiring, sharing, storing and utilizing of knowledge activities (Lee & Kim 2001). The subsequent integration stage institutionalizes knowledge activities into daily work (Lee & Kim 2001), and then knowledge activities are institutionalized into the organization’s network of external stakeholders (Lee & Kim 2001).

Carlile and Rebentisch (2003) study knowledge transfer and suggest the use of a knowledge transfer cycle of transforming, storing and retrieving knowledge. While studying a cross-disciplinary product development team, Carlile (2004) describes knowledge processes on three levels in a 3-T framework, which proposes how to manage knowledge across boundaries (Carlile 2004). Carlile (2004) suggests that syntactic, semantic and pragmatic boundaries relate to transfer, translation and transformation processes. As illustrated in Figure 7, the boundaries between two actors (A and B) increase in complexity as the actors pursue novelty (Carlile 2004). At the syntactic level, actors utilize a transfer or information-processing approach in knowledge processes. In this syntactic context, actors share and asses their knowledge and need a common language for the work they do (Carlile 2004).

At the semantic level, actors take a translation or interpretive approach to knowledge processes (Carlile 2004). In the semantic context, actors create common meaning and need to negotiate agreements across organizational boundaries (Carlile 2004). At the pragmatic level where innovation is desired, actors takes a transformational or political approach to knowledge processes (Carlile 2004). In the pragmatic context, actors create common interests that require significant practical and political effort (Carlile 2004).

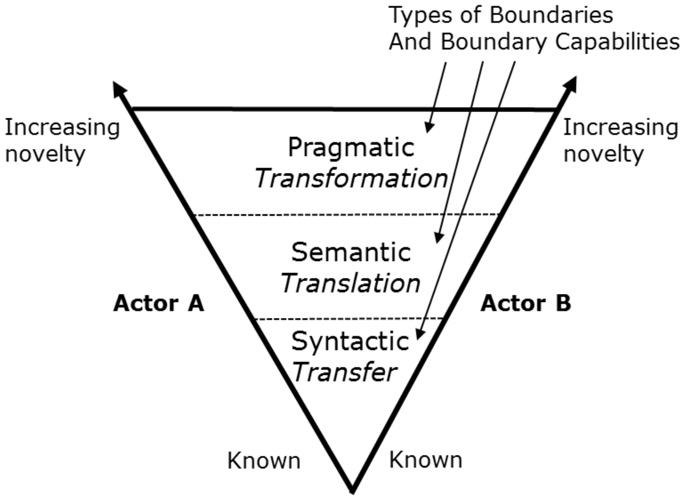


Figure 7. 3T framework for managing transfer, translation and transformation knowledge processes across syntactic, semantic and pragmatic boundaries (Carlile 2004).

Carlile (2004) describes a context of designers with different expertise. When considering organizational members' development of product realization, the context includes cross functions of organizational members with a more diverse background and knowledge base (skills and competencies). However, while knowledge can be a source of innovation, it can also be a barrier to innovation and product development (Carlile 2002). Carlile (2002) studies groups of design engineers and manufacturing engineers and finds that working across functions generates problematic boundaries, assuming that knowledge is localized, embedded and invested within a function.

3.3 Summary

In this chapter, I have first discussed knowledge creation, knowledge usage and knowledge processing in product realization. Knowledge processes in product realization are divided into knowledge creation, knowledge usage and knowledge processing. These knowledge processes are grouped according to how they are applied in product realization. Second, I have studied frameworks for knowledge processes to identify elements that support a CII-program, addressing challenges identified in Chapter 2. The 3T framework support my considerations about elements that facilitate information processing, create shared meaning and negotiate common interests.

4 An organizational learning perspective on integration of new work practices

The previous chapters described challenges in the cross-functional work practices in product realization. The next step is then to understand the organizational learning process of integrating new work practices into product realization and identify activities that facilitate this integration. For that purpose, this chapter describe organizational learning processes, relates them to integration of new work practices, and herewith provide an answer for the third research question:

RQ3: What activities facilitate organizational learning processes in product realization?

In the following, I first present theoretical perspectives on organizations, organizational learning and organizational learning processes. Second, I explore organizational learning frameworks that explains how the organizational learning processes interacts in a flow through organizational levels. Third, I focus on the 4I framework (Crossan et al. 1999) in order to apply concepts for facilitating activities in the analysis of case data.

4.1 Perspectives and organizational learning processes

I presented key concepts within organizational learning in section 1.3. These key concepts provide me with a basic vocabulary for exploring learning as an organizational phenomenon. In this section, I take a step further into organizational learning literature to explore organizational learning processes, the underlying assumptions and purpose. In the following, I first present different theoretical perspectives on organizations and organizational learning. Then I explore organizational learning processes within organizational learning literature to understand how they differ, what elements they consists of.

Perspectives on organizations and organizational learning

Scholars take different theoretical perspectives on organizations within organizational learning literature. The theoretical perspective on organizations explain sources of learning, actions related to learning, and subsequently accumulates learnings. As Grant (1996) explain: “Theories of the firm are conceptualizations and models of business enterprises which explain and predict their structure and behaviors.” Table 10 provides an overview of the different theoretical perspectives and their definitions.

10. Theoretical perspectives on organizations and organizational learning.		
Theory	**Perspectives on organizations and organizational learning**	**Exemplar references**
Behavioral theory of the firm	"Organizations are collections of subunits learning in an environment that consists largely of other collections of learning subunits (Cangelosi & Dill 1965)." (Levitt & March 1988, p. 331)	(Cyert & March 1963) (Levitt & March 1988) (Levinthal & March 1993)
Theory of action	"espoused theory" explains a given pattern of activity, and "theory-in-use" means the theory of action implicit in the pattern of activities	(Argyris & Schon 1996) (Argyris 2003)
Absorptive capacity	is the "… ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen & Levinthal 1990, p. 128)	(Cohen & Levinthal 1990) (Lane 2006)
Resource-based	"Firm's resources according to Barney (1991) comprise all assets, skills, organisational processes, attributes; information and know-hows in which controlled by firm and enable them to implement strategies more efficiently and effectively." (Almahendra & Ambos 2015, p. 18)	(Barney 1991)
Knowledge-based theory of the firm	"… identifies the primary role of the firm as integrating the specialist knowledge resident in individuals into goods and services."	(Grant 1996, p. 120)
Evolutionary theory	"… evolution refers to change or transformation over time … Thus, it can readily apply to organizations as well as birds, insects, slime mold, and humans. The three underpinnings of evolutionary theory are variation (organisms of a species differ on traits), at the selection (these differences sometimes make a difference in the organisms ability to survive), and retention (traits can be passed from one generation to another)." (O'Reilly III et al. 2009, p. 77)	(O'Reilly III et al. 2009)
Complexity theory	"Complexity theories represent a research approach that makes philosophical assumptions of the emerging worldview, which include holism, perspective observation, non-linearity, synchronicity, mutual causation, relationship as unit of analysis, etc. (Dent 1999)." (Anderson 1999, p. 118)	(Anderson 1999) (Chiva et al. 2010) (Chiva & Habib 2015)

Scholars such as Levitt, March, Levinthal, and Cyert base their perspective on a behavioral theory of the firm perceiving organizations as adaptive or experiential learning systems (Cyert & March 1963; Levitt & March 1988; Levinthal & March 1993; Miner & Mezias 1996; Almahendra & Ambos 2015). Levitt & March (1988) perceive organizational learning as routine-based, history-dependent, and target-oriented. This means that routines such as procedures, forms, and strategies directs organizational behavior (what the organization as a collective do) and that outcome of doing provides feedback for incremental learning (Levitt & March 1988). Targets on the other hand directs organizational behavior toward achieving a condition different from current condition (Levitt & March 1988). Organizations learn from their own (routines and history) as well as others (targets) experience and integrate interpretations of these experiences into concepts for the organizational work (Levitt & March 1988). Levinthal & March (1993) described simplification and specialization as two learning mechanisms where interpretation delineates the experience. Simplification mechanisms seek to limit interactions or simplify the effect of the experience and specialization mechanisms seek to drive a narrow focus on specific areas (Levinthal & March 1993). Organizations has memories of prior experience that is coded, stored and can be retrieved for use (Levitt & March 1988). Organizational memory comprise rules, technologies, beliefs and cultures socially controlling the organization as a system (Levitt & March 1988). As such, organizations are adaptive learning systems of individuals and groups learning from experience, from each other and influencing each other's learnings (Levitt & March 1988; March 1991; Levinthal & March 1993). However, focusing short-term, favoring effect closely related to the learner, and ignoring failures are three core implications for organizational learning (Levinthal & March 1993).

In the concept of "theory of action", Argyris & Schon (1996) identifies two forms of theory: "espoused theory" that explains a given pattern of activity, and "theory-in-use" that means the theory of action implicit in the pattern of activities (Argyris & Schon 1996). These definitions underline organizational learning as processes that can be multi-level and collective within an organization. According to Argyris (1996; 2003) "theory of action" differ from behavioral theory of the firm by including defensive reasoning. Defensive reasoning imply that individuals defend their actions thus restrain changing behavior and learning (Argyris 2003).

Cohen & Levinthal (1990) focus on organizations capacity to absorb and commercialize external knowledge and "… argue that the ability to evaluate and utilize outside knowledge is largely a function of the level of prior related knowledge" (Cohen & Levinthal 1990, p. 128). They study cognitive structures underlying learning on individual level and relates it organizational level (Cohen & Levinthal 1990). Cohen & Levinthal (1990) builds on the assumption that experience from prior learnings influence subsequent learnings. This assumption is also found in literature on learning curves (Argote 2013) and "learning to learn" or deuterolearning (Bateson 2000). On the other hand, this also means that learning is more difficult when there is less initial knowledge about a topic, which is relevant when the degree of novelty is high. Novelty is high e.g. when organizations try to apply new technologies. On an organizational level, an organizations absorptive capacity depends on individual organizational members' cognitive abilities (Cohen & Levinthal 1990). An organizations knowledge structures such as communication system carries information that is distinct to an organization though closely related to individual boundary spanning roles such as gatekeepers (Cohen & Levinthal 1990). An organizations absorptive capacity is ingrained in connections between organizational members (Nelson & Winter 1982; Cohen & Levinthal 1990). Furthermore, cross-functional absorptive capacity may benefit from redundancy or overlapping expertise e.g. between design and manufacturing (Cohen & Levinthal 1990).

Both the resource-based view and evolutionary theory aims at understanding why some organizations outmatch others (Argote 2013). According to scholars taking a resource-based view, organizations comprise resources such as skills, procedures, assets, information and know-how to execute strategies (Barney 1991; Almahendra & Ambos 2015). This means that organizations possess tacit and explicit knowledge that individuals and groups generate, store and share (Hislop 2013). Organizational learning in this perspective overlaps knowledge processes and knowledge-based theory of the firm (Chiva & Alegre 2005; Hislop 2013).

According to knowledge-based theory of the firm, knowledge is the most strategically important resource for the firm especially if it is difficult to replicate and copy (Grant 1996; Hislop 2013). It is management's primary task to establish coordinating mechanisms that integrate specialized knowledge into goods and services (Grant 1996). Grant (1996) propose that organizations provide effective mechanisms for sharing and integrating knowledge between individuals and reconcile conflicting goals for organizational members (Hislop 2013).

O'Reilly & Tushman (2013) applying evolutionary theory on organizations focus on organizational ambidexterity as an organizations ability to perform and deliver incremental as well as radical innovations. In this evolutionary perspective, scholars study antecedents, consequences, and mediating roles of explorative and exploitative learning processes learning (Raisch & Birkinshaw 2008; Simsek 2009; O'Reilly & Tushman 2013; Almahendra & Ambos 2015). Scholars studying organizational ambidexterity apply different perspectives on organizations that represent behavioral theory of the firm, absorptive capacity, resource based view, evolutionary theory and knowledge based view (Almahendra & Ambos 2015). While most research within this field focus on organizational ambidexterity in a strategic and inter-organizational perspective, only few study organizational learning processes at operational level (Gupta et al. 2006; Birkinshaw & Gupta 2013).

In a final stream of research scholars across several disciplines apply complexity theories to explain organizational learning processes (Anderson 1999; Chiva et al. 2010). Complexity theories is based on an emerging and holistic worldview that takes relationships as unit of analysis (Chiva et al. 2010). From this perspective, scholars seek to grasp and simplify the complexity of organizations as adaptive systems (Anderson 1999). Complex adaptive organizational systems are characterized by the following four key elements: "agents with schemata, self-organizing networks sustained by importing energy, coevolution to the edge of chaos, and system evolution based on recombination" (Anderson 1999, p. 2016). Individuals, groups and coalitions of groups are agents the behave according to a schema that might or might not be similar (Anderson 1999). Agents relate and interact with each other in self-organizing networks that imports energy to sustain the network (Anderson 1999). Furthermore, agents evolves with one another, constantly causing change and push equilibrium to the edge of chaos (Anderson 1999). In this way, complex adaptive organizational systems learn and evolve through agents (individually and collectively) entering, exiting and transforming the organizational network as recombination's (Anderson 1999; Chiva et al. 2010; Chiva & Habib 2015).

Organizational learning processes

The different streams of research describe dualities of organizational learning processes such as single-loop or double-loop learning (Argyris & Schon 1996), adaptive or generative learning (Chiva et al. 2010), and exploitative or explorative learning (March 1991). Table 11 lists the organizational learning processes and their definitions.

11. Definitions and exemplar references on organizational learning processes		
Exemplar references	**Organizational learning processes**	**Definitions or description**
(March 1991, p. 71)	Explorative learning	"Exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation."
	Exploitative learning	"Exploitation includes such things as refinement, choice, production, efficiency, selection, implementation, execution."
(Argyris & Schon 1996, p. 20-21)	Single-loop learning	"By single-loop learning we mean instrumental learning that changes strategies of action or assumptions underlying strategies in ways that leave the values of a theory of action unchanged."
	Double-loop learning	"By double-loop learning, we mean learning that results in a change in the values of theory-in use, as well as in its strategies and assumptions."
(Miner & Mezias 1996, p. 91)	Trial-and-error Learning	Repetition of successful routines; behavior and competencies; standard operating procedures.
	Inferential Learning	Informed observation; active experimentation; interpretation and information acquisition.
	Vicarious Learning	Observation and copying of successful routines; deduction from outcomes
	Generative Learning.	Active and creative discovery processes
(Lane 2006, p. 857 - 858)	Exploratory learning	"… is used to recognize and understand new external knowledge."
	Transformative learning	"… to assimilate valuable external knowledge"
	Exploitative learning,	"… is used to apply the assimilated external knowledge."
(Chiva & Habib 2015, p. 350)	Zero learning	"… internalizing norms, routines, procedures or knowledge."
(Chiva et al. 2010, p. 116)	Adaptive learning	"Adaptive learning involves any improvement or development of the explicate order through a process of self-organization. Self-organization is a self-referential process characterized by logic, deductive reasoning, concentration, discussion and improvement."
	Generative Learning	"Generative learning involves any approach to the implicate order through a process of self-transcendence. Self-transcendence is a holo-organizational process characterized by intuition, attention, dialogue and inquiry."

March's study (1991) takes a trade-off point of view on management's distributing of resources for explorative and exploitative processes perceiving exploration and exploitation as adaptive processes competing for scarce resources. A competition causing tensions between organizational sub-systems and subsequently positioning management in a priority dilemma (O'Reilly III & Tushman 2011; Gibson & Birkinshaw 2004; Gupta et al. 2006). The field organizational ambidexterity focuses on two types of learning behaviors for organizational learning (O'Reilly & Tushman 2013; Simsek 2009; Raisch & Birkinshaw 2008; Almahendra & Ambos 2015). Trial-and-error experimentation and search for knowledge is characterized as an explorative learning behavior related to innovation and organizational refinement and use of existing knowledge is an exploitative learning behavior related to efficiency (Levitt & March 1988; March 1991; Rodan 2005; Almahendra & Ambos 2015). Researchers tends to split explorative and exploitative learning behaviors organizationally or temporarily, and connecting learning behaviors to incremental or revolutionary change (O'Reilly III et al. 2009; Tushman & O'Reilly III 1996; Gupta et al. 2006). Others propose managers should be capable of handling both types of learning behavior (Gibson & Birkinshaw 2004; Birkinshaw & Gupta 2013; O'Reilly III & Tushman 2011).

Single-loop and double-loop learning coined by Argyris and Schon (1996) describes two different learning systems. The notion "learning system" emphasize the learning within an organization that is an open system interacting across its boundaries with the surrounding environment (Argyris & Schon 1996; March 1991). The outcome of single-loop learning retain organizational members' theory-in use (Argyris & Schon 1996). This means that changes made in a single-loop learning process refines the organizational system and enlarge the organizational systems current knowledge (Argyris & Schon 1996). In contrast, double-loop learning imply challenging and changing organizational members' theory-in-use and hereby changing the learning system itself (Argyris & Schon 1996). Double-loop learning in an organization imply changing basic assumptions and consequently its culture (Argyris & Schon 1996; Schein 2010). Single-loop and double-loop learning is distinguished by a change in thinking or in the mindset (Argyris & Schon 1996; Schein 2010). Argyris and Schon (1996) distinguish between productive reasoning and defensive reasoning. An organization with a model O-I is unlikely to learn to alter its governing viable, norms and assumptions (Argyris & Schon 1996). It require organizational inquiry into double-loop issues to enter into a model O-II learning system (Argyris & Schon 1996). Argyris and

Schon (1996) suggest that action strategies for interventions toward O-II learning systems could imply:

> “Design situations where participants can be origins of action and experience high personal causation.
> Task is jointly controlled.
> Protection of self is a joint enterprise and oriented toward growth.
> Bilateral protection of others.” (Argyris & Schon 1996, p. 118)

Miner & Mezias (1996) propose four different types of organizational learning processes: Trial-and-error learning, Inferential learning, vicarious learning, and generative learning. These four types of organizational learning builds on single-loop and double-loop learning as well as explorative and exploitative learning (Miner & Mezias 1996). Miner & Mezias (1996) recognizes that learning exists on learning on individual, group, organizational and inter-organizational level, though focus on the organizational level. Trial-and error learning associates with following standard operating procedures and improving these through solving problems (Miner & Mezias 1996). Inferential learning arise from observing variations or experimenting (Miner & Mezias 1996). vicarious learning reach outside organizational boundaries to copy routines and procedures from others (Miner & Mezias 1996). Finally, describes generative learning a more creative discovery and investigation (Miner & Mezias 1996).

In reviewing literature on absorptive capacity, Lane (2006) separates an organizations absorptive capacity into three dimensions. Exploratory learning is to recognize and understand new external knowledge, transformative learning is then used for assimilating external knowledge with existing internal knowledge, and exploitative learning is to disseminate the use of assimilated external knowledge (Lane 2006). External drivers in organizational learning processes in breath and depths of knowledge, learning relationships and the organizations environment (Lane 2006). Internal drivers include organizational structure, strategy and individual cognition (Lane 2006). Outcome of learning processes is linked to innovation performance, an organizations overall performance and commercial application of acquired knowledge (Lane 2006). Knowledge outputs can change organizational member’s mental models and support further development of an organizations structures and processes (Lane 2006).

In continuation, adaptive and generative learning comprise a change that can be incremental or radical and individual or social (Chiva et al. 2010). To explain what changes, Chiva et al. (2010) use the notions “implicate” and “explicate” order where “implicate” order is an implicit, holographic order represented in every individual, connected with every individual (Chiva et al. 2010). When the “implicate” order is interpreted, it becomes an “explicate” order (Chiva et al. 2010). Zero learning on the other hand generates no change in the “explicate” order and as such no learning (Chiva & Habib 2015). Chiva and Habib (2015) relates zero, adaptive and generative learning to Bateson’s (2000) typology of learning levels. Furthermore, Chiva and Habib (2015) relates adaptive to single-loop learning and generative to double-loop learning.

In order to understand the above mentioned organizational learning processes level of learning I categorize them to Bateson’s (2000) typology of learning shown in table 12. “Learning” implies a change that can be progressive or regressive in nature (Bateson 2000). Progression implies that an individual improves its ability to learn effectively, whereas regression implies discarding new behaviors and falling back to prior behaviors that was previously effective (Bateson 2000). If learning is a change, then learning must be a movement or process that performed at a rate that can be changed. Deuterolearning is the ability of learning to learn which means that the learning made in a context can be transferred to another context and becomes increasingly better at solving problems (Bateson 2000). By repeating solving problems, the individual becomes faster at solving problems of similar kind in different contexts (Bateson 2000). Consequently, the individual grows a habit or pattern of actions in solving problems to economize its efforts (Bateson 2000). Learning to learn in a new context entails a use of this habit and requires the creation of a new habit and possible breaking the existing habit (Bateson 2000).

12. Organizational learning processes related to Bateson's (2000) typology of learning levels.				
Zero learning	***Level I***	***Level II***	***Level III***	***Reference***
"…is characterized by specificity of response, which - right or wrong - is not subject to correction"	"… is change in specificity of response by correction of errors of choice within a set of alternatives. Learning"	"…is change in the process of Learning /, e.g., a corrective change in the set of alternatives from which choice is made, or it is a change in how the sequence of experience is punctuated" (Deutero-learning or learning to learn)	"… is change in the process of Learning II, e.g., a corrective change in the system of sets of alternatives from which choice is made"	(Bateson 2000)
		Exploitative Learning	Explorative Learning	(March 1991)
		Single-loop Learning	Double-loop Learning	(Argyris 2003)
	Trial-and-error Learning	Inferential Learning vicarious Learning	Generative Learning	(Miner & Mezias 1996)
No Learning	Zero Learning	Adaptive Learning	Generative Learning	(Chiva & Habib 2015)

An underlying assumption in categorizing organizational learning processes is that activities in single-loop, adaptive, inferential or vicarious learning leads to Level II learning. Respectively that double-loop or generative learning leads to Level III learning.

In this study, I apply behavioral theory of the firm to understand product realization processes as an environment in which collections of subunits collaborate in learning collectively and integrate the outcome (new work practices) into the common primary task (product realization). Furthermore, I apply exploitative and explorative learning processes to distinguish between learning that relates to level II and level III respectively.

4.2 Organizational learning frameworks

In the following, I apply the 4I organizational learning framework to identify potential activities that facilitate organizational learning processes. The 4I framework is a foundation for theory development and captures the tension between explorative and exploitative learning processes as well as including multiple organizational levels (Lengnick-Hall & Inocencio-Gray 2013). Crossan et al.'s (1999) 4I framework for organizational learning processes links the individual, group, and organizational levels into an organizational learning process through intuiting, interpreting, integrating, and institutionalizing. Crossan et al. (1999) claim that few organizational learning frameworks illustrate the tension between exploration and exploitation. Feedback and feedforward as explorative and exploitative learning processes spanning organizational levels from individual over group to organization. Figure 8 visualize the 4I framework. In the following, I present the 4I framework and empirical studies applying the framework.

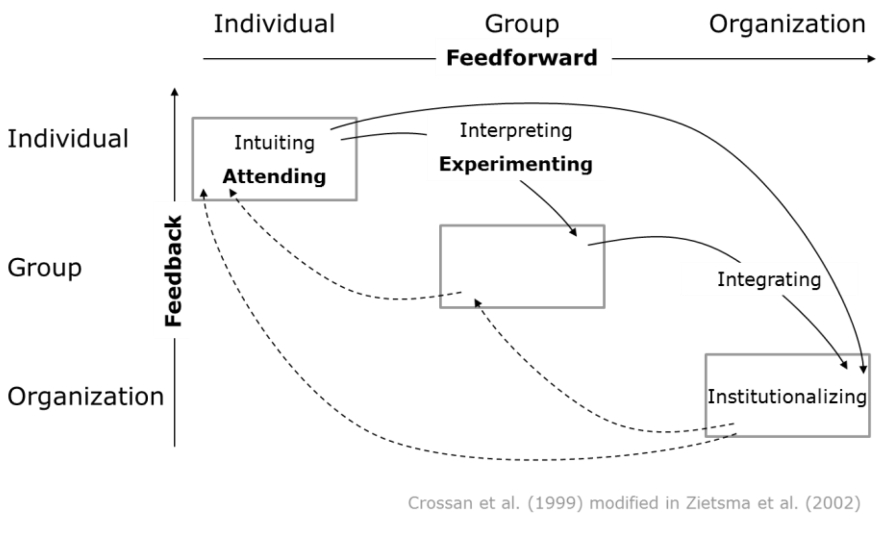


Figure 8. 4I framework for organizational learning processes.

Intuiting, Interpreting, Integrating and Institutionalizing is four learning processes that occur on individual, group and organization levels (Crossan et al. 1999). The 4I framework describes how learning processes binds the structure together in a Feedforward and a feedback process spanning organizational levels (Crossan et al. 1999). Intuiting and Interpreting learning processes occur on individual and group levels, Interpreting and Integrating occur on group and organization level, and Integrating and Institutionalizing occur on organizational level (Crossan et al. 1999). Zietsma et al. (2002) challenged the model in an empirical case study and added Attending and Experimenting as two learning processes to the model. Additionally extending Zietsma et al. (2002) version of the 4I Framework, Jones & Macpherson (2006) adds Intertwining as a learning process and an Inter-organizational level to the framework. Focusing on power relation in organizational learning processes, Lawrence et al. (2005) added social politics processes to the model. In a literature review, Berson et al. (2006) applied the 4I Framework to study the connection between leadership and organizational learning. The 4I framework are used in several different contexts such as entrepreneurship (Dutta & Crossan 2005; El-Awad et al. 2017), strategic renewal (Crossan & Berdrow 2003), HRM and innovation (Lin & Sanders 2017), and business model innovation (Frankenberger et al. 2013).

Feedforward organizational learning processes

Crossan et al. (1999) claim that feedforward is an explorative process, which in this context utilize individual experience from developing product realization and knowledge such as problem solving methods and activities facilitating organizational learning processes.

Individuals *intuiting* personal experience and knowledge is on one hand being conscious about patterns or possibilities and on the other hand pay attention to what is subconscious (Crossan et al. 1999). Routine in working on similar tasks adds tacit knowledge to work processes and becomes more subconscious and experts intuition supports exploitation of existing knowledge (Crossan et al. 1999). “Entrepreneurial” intuition for new opportunities supports exploration (Crossan et al. 1999). Crossan et al. (1999) suggests using metaphors when lacking consistent language to describe embryonic insights. Metaphors can be helpful to make associations initiating interpretations of the newly gained insight e.g. where a designer involve other organizational members in exploring consequences such as how and where the insight is applicable (Crossan et al. 1999). Intuition involves individual insights that don’t rely on direct management’s influence but also from other relations inside and outside the organization (Berson et al. 2006). Attending to conflicting information from different sources initiated in Zietsma et al.’s

(2002) case that organizational members paid attention to their them-and-us pattern in a conflict.

Scholars (Zietsma et al. 2002; Crossan & Berdrow 2003; Schulze et al. 2013) describe activities and events related to organizational learning processes as part of their case studies using the 4I framework. Table 13 show examples of these activities in Intuiting learning processes.

13. Activities facilitating Intuiting/attending learning processes.

Activities in Intuiting	***Examples***	***Reference***
Communicate	- Enabling people to understand and communicate the process and its performance through value stream mapping	(Schulze et al. 2013)
Reflection	- Recognizing performance gaps, patterns, and problems' root causes	(Schulze et al. 2013)
Challenging cognitive maps	- Stimulating revisions of their prior understanding - Direct exposure to alternate views - Openness to diverse opinions - Situations that evoke associations to prior situations	(Schulze et al. 2013) (Zietsma et al. 2002) (Crossan & Berdrow 2003)

Schulze et al.(2013) apply value stream mapping[1] for explicating otherwise tacit knowledge about new product development processes and their performance. Using value stream mapping help participants express how they worked and their reasons for undertaking specific tasks that is otherwise subconsciously taken for granted (Schulze et al. 2013). Value stream mapping give the participants a common language for reflecting on performance gaps, patterns, and problems' root causes, and challenging their cognitive maps of how new product development process is carried out (Schulze et al. 2013). In their case study of a strategic change, Crossan and Berdrow (2003) reports that respondents saw entrepreneurial individuals as primary source of intuition. In addition, a new CEO's prior experience evoked reflection on inadequate routines (Crossan & Berdrow 2003). Zietsma et al. (2002) in their case study, observed that direct exposure to alternate views and relational

[1] Value-stream mapping is a lean-management method for analyzing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer. https://en.wikipedia.org/wiki/Value_stream_mapping

ties with those holding these alternate views facilitated attending to conflicts. On the individual level, it was unconstrained actors with an openness to divergent views that facilitated personal intuition (Zietsma et al. 2002).

The outcome of the Intuiting learning process is an outline of the new product development process and its metrics as-is (Schulze et al. 2013). Participants had a specific intuition about organizing new product development projects and their performance before the value stream mapping, though struggling to express reasons for undertaking specific tasks (Schulze et al. 2013).

Intuiting learning processes is primarily occurring on an individual level in being aware of patterns in working, though Schulze et al.(2013) applied a group level process bringing up subconscious patterns of new product development. An individual designer or operator might recognize a problem as working on a specific task, however, when it comes to developing cross-functional processes initiating Intuiting learning processes is just as well facilitated deliberately by forming a group.

As a limitation to the intuiting learning process, insufficient language to describe the present situation can stifle sharing this intuition with others (Schulze et al. 2013). Zietsma et al.(2002) observed that factors such as isolation from direct pressures, previously institutionalized learning and perceptions of illegitimacy of pressure imped the organizational learning process.

Interpreting the explicated Intuition is then carried out between individuals or in groups (Crossan et al. 1999). Insights and ideas are gain from communicating with other individuals or through action (Crossan et al. 1999) such as *experimenting* (Zietsma et al. 2002). Individuals taking part of a process of communicating, experimenting and action gain a shared cognitive map about the object they are focusing on (Crossan et al. 1999). According to Crossan et al. (1999), “Interpreting is a social activity that creates and refines common language, clarifies images, and creates shared meaning and understanding” (Crossan et al. 1999, p. 528). As such, developing a shared language play a pivotal role in forming the type of communication (Crossan et al. 1999). Additionally can leaders play an important role in supporting individuals in organizational learning processes (Berson et al. 2006).

The cognitive maps are affected by the environment (Crossan et al. 1999). According to (Weick 1979), “people are more likely to "see something when they believe it" rather than "believe it when they see it."” (Crossan et al. 1999, p. 528). Uncertainty and ambiguity in the information that comes out of the stimuli can course confusion that leads individuals to freeze or paralyze in double bind situation (Bateson 2000). Leaders are responsible of framing goals for learning thus responsible for clarifying the context (Berson et al. 2006). Challenging cognitive maps, collective thinking, dialog, discussion, storytelling, language, inquiry and reflection exemplified in case studies using the 4I framework are shown in table 14.

14. Activities facilitating Interpreting/experimenting learning processes

Activities in Intuiting	***Examples***	***Reference***
Challenging cognitive maps	- Individuals challenged by the group - Supervisor contradicted by subordinates - New CEO brought new perspectives	(Schulze et al. 2013) (Crossan & Berdrow 2003)
Collective thinking	- Improving quality of conversation through Value stream mapping - Initiating programs - Internalization of divergent stakeholder views - Joint sense-making through data collection and modelling	(Schulze et al. 2013) (Crossan & Berdrow 2003) (Zietsma et al. 2002)
Dialog	- Fostered by Value stream mapping - Focusing on factual data - Speak-up program	(Schulze et al. 2013) (Crossan & Berdrow 2003)
Storytelling	- Captured and promulgated by employees stories	(Schulze et al. 2013)
Visualizations	- Value stream mapping with its symbols, metrics, and systematic procedure	(Schulze et al. 2013)
Inquiry	- Improving quality of conversation through Value stream mapping	(Schulze et al. 2013)
Reflection	- Stimulated by shared observations	(Schulze et al. 2013)

Schulze et al. (2013) observe that value stream mapping is valuable to participants in cross-functional workshops as its clear language of symbols, metrics and systematic procedure form a fertile ground for dialog, inquiry, and reflection. This collective process productively challenges individuals collective maps, but also give rise to counterproductive discussions when quality of the visualized process was low (Schulze et al. 2013). Organizational members’ credited their interpretations to management’s communication in

Crossan and Berdrow's (2003) case study. A newly appointed CEO brought new perspectives to the organization and challenged organizational members' perception of the company (Crossan & Berdrow 2003). In Zietsma et al.'s (2002) case study, internalization of divergent stakeholder views and joint sense-making through data collection and modelling facilitated interpretation and experimentation.

Value stream mapping clarified that there were different understandings of new product development processes in different functions (Schulze et al. 2013). The collective dialog, inquiry and reflection in value stream mapping reduced ambiguity about work practices in new product development processes (Schulze et al. 2013). The participants gained shared understanding of the actual work practices and also a method for sharing their understanding of product development processes (Schulze et al. 2013). In Crossan & Berdrow's (2003) study, organizational members gained awareness of the organization's situation (competitive pressure, customer needs) and their own contribution. The organization gained new insights and ways of thinking about the business conditions (Crossan & Berdrow 2003).

Limitations to value stream mapping became apparent when too few people participated in the workshop as less information was shared, which subsequently lowered quality of the visualized process (Schulze et al. 2013). Organizational level diversity in interpretation of the situation and change challenge the following integration process (Crossan & Berdrow 2003). Individuals isolated from new learnings on the other hand imped the learning process (Zietsma et al. 2002).

The Interpreting learning process comprise interactions between individuals in the group in forming individual and shared understandings (Schulze et al. 2013). Schulze et al. (2013) additionally observed that participants sought confirmation from colleagues outside the workshop. Crossan & Berdrow's (2003) study, report individuals interpretations of organizational level activities.

Integrating learning processes starts as the interpreting moves into a group of individuals comprising development of coherence and collective action (Crossan et al. 1999). Coherence builds on the shared understanding of the current situation e.g. product realization process (Crossan et al. 1999).

Language explaining the shared understanding is further refined in a continuing dialog in the group (Crossan et al. 1999). Crossan et al. (1999) points attention to decisions made in a consensus process risks a groupthink outcome.

Crossan et al. (1999) do not explain how a group comes from dialog to collective action or how integrations of knowledge or new insights are justified. Knowledge about e.g. technology, methods, materials contribute with options for changing products, production as well as the entire product realization process. Whether this brought in knowledge “pollute” the system or contribute with new options is part of a socialization process (March 1991) and undergo a “justification” (Nonaka 1994) by organizational members. Then turning to the empirical cases a few observations emerge as shown in table 15.

15. Activities facilitating Integrating learning processes

Activities in Intuiting	***Examples***	***Reference***
Collective thinking	- Observing less collective thinking between few participants	(Schulze et al. 2013)
Dialog	- Leading to agreement on changed practice - Observing less discussion between few participants - Broadening views of functions - Specifying details Avoid resource allocation trade-offs	(Schulze et al. 2013) (Crossan & Berdrow 2003)
Visualization	- Understanding interdependencies between functions through value stream mapping.	(Schulze et al. 2013)
Shared meaning	- Capturing a holistic view of the situation Challenge in developing a shared understanding of how to proceed in change	(Schulze et al. 2013) (Crossan & Berdrow 2003)
Justification	- Tightly managed implementation process reduce critical voices Allocation of power and resources to integration	(Crossan & Berdrow 2003) (Zietsma et al. 2002)

Schulze et al. (2013) reports on continuing collective thinking and discussion In line with Crossan et al. (1999). The integrating learning process leads participants to specify details of work practices, broaden views of functions, understand interdependencies between functions, and capture a holistic view of the situation (Schulze et al. 2013). One observation reports how a discussion among participants leads to changed practice as a group challenged an engineer on the necessity of three tests of a product (Schulze et al. 2013). The integration process reported in Crossan & Berdrow's (2003) study was tightly managed in contrast to being open and participative. Also, discussions about resource trade-offs was avoided in order to ensure implementation (Crossan & Berdrow 2003). Similarly Zietsma et al.'s (2002) observed that allocation of power and resources thus providing autonomy of action or endorsement facilitated integration.

Value stream mapping facilitates a continuing conversation on steps in new product development processes adding perspectives from diverse participants (Schulze et al. 2013). The outcome is further inquiry, shared knowledge of processes, and identification of problems directing future improvements of processes (Schulze et al. 2013). In the case of Crossan & Berdrow (2003) the outcome is groups of stakeholders alienated in the process.

Similar to the interpretation process, limited participation leads to less exploration of the actual situation and subsequently limited effect (Schulze et al. 2013). Schulze et al. (2013) also observed "interpretive barriers" and "departmental thought worlds" as reasons for different participants different perceptions of the same situations. According to Crossan & Berdrow's (2003), the threat of bankruptcy influenced the implementation process and caused variation in focus of integration.

The organizational dimensions reported in the empirical cases span the individual and group level (Schulze et al. 2013) as well as the organizational level (Zietsma et al. 2002; Crossan & Berdrow 2003).

Feedback organizational learning processes

Organizational members learn from experience about what works and does not work in daily work (Levinthal & March 1993). It is an experience gained in the feedforward process. Where feedforward is an explorative process of where individuals and groups learn from dialog, inquiry, reflection and experimentation, feedback is an exploitative process embedding the gained knowledge into the organization. Crossan et al. (1999) builds on the assumption that organizations are more than collections individuals. Individuals learn though "[s]ome learning is embedded in the systems, structures, strategy, routines, prescribed practices of the organization, and inscribed practices of the organization, and investments in information systems and infrastructure." (Crossan et al. 1999, p. 529).

Institutionalizing is the learning process of ensuring routinized actions (Crossan et al. 1999). Institutionalization gradually adds routines or patterns of behavior to an organization as it grows (Crossan et al. 1999). A new organization will eventually reach a point where it no longer can rely on spontaneous interactions to interpret, integrate, and take coherent action (Crossan et al. 1999). From that point, an organization becomes increasingly formalized and routinized. Additionally, influential organization members (or specifically management) ensures that the formalized organizational system perform as expected. For this purpose, they also need formal systems, structures, routines and so forth (Crossan et al. 1999). Lengnick-Hall & Inocencio-Gray (2013) study institutionalizing organizational learning across four work contexts: Routine, Engineering, Craft, and Non-routine. Routine work contexts institutionalize learnings through written procedures and rules of conduct (Lengnick-Hall & Inocencio-Gray 2013). In a similar way, engineering work contexts institutionalize learnings in manuals and standard operating procedures (Lengnick-Hall & Inocencio-Gray 2013). Craft work contexts on the other hand apply ritualized procedures such as reviews and assessments (Lengnick-Hall & Inocencio-Gray 2013). In non-routine work procedures links to individual skills and as such difficult to challenge and institutionalize (Lengnick-Hall & Inocencio-Gray 2013).

Organizational members apply routinization to store organizational knowledge from their experience of what works and doesn't work in product realization (Levinthal & March 1993; Adler et al. 1999; Womack 2003). In practice, organizational knowledge is stored in various forms such as rules, procedures, product documentation, standard operating procedures (SOP), workplace layout or other physical or electronic artefacts (Nonaka 1994; Levinthal & March 1993; Womack 2003). Additionally, knowledge is stored tacitly as embodied individual skills in working (Nonaka 1994; Levinthal & March 1993). Routinized knowledge ensure transport of experience between individuals to reduce variability in work performance (Levinthal & March 1993; Womack 2003). New members of an organization is trained in their new work and socialized into the organizations accepted behavior (March 1991).

In the empirical cases using the 4I framework to describe learning processes, the facilitating activities in institutionalizing learning processes comprise collective action, collective thinking, and discussion as shown in table 16.

16. Activities facilitating Institutionalizing learning processes		
Activities in Intuiting	***Examples***	***Reference***
Collective action	- defined tasks and specified actions in value stream mapping workshops - involved engineers in continuous improvement of sub-processes and projects in Obeya - ensured coherent action trough value stream mapping - Implementation of new technology and procedures as well as retaining existing systems and procedures. - Offering new products and services	(Schulze et al. 2013) (Crossan & Berdrow 2003)
Collective thinking	- switched between product oriented thinking and process thinking in Obeya - developing new strategies - endorsement of trusted niche representatives	(Schulze et al. 2013) (Crossan & Berdrow 2003) (Zietsma et al. 2002)
Dialog	- identified and discussed problems in value stream mapping workshops	(Schulze et al. 2013)
Unlearning	- erosion of support for previously institutionalized interpretations	(Zietsma et al. 2002)

According to Schulze et al. (2013), participants in value stream mapping workshops takes collective action on identified and discussed problems. A dedicated room (Obeya[2]) with value stream maps form a basis for continuation of collective thinking on products and processes involving engineers in continuous improvement of their work processes (Schulze et al. 2013). In Crossan & Berdrow's (2003) case study, the organization implemented a range of new technologies and procedures while retaining some of the existing. As part of the change process the organization developed new products and services as well as new strategies (Crossan & Berdrow 2003). As well as institutionalizing new work practices and cognitive maps, erosion of support to previously institutionalized interpretation imply unlearning

[2] Obeya or Oobeya (from Japanese 大部屋 "large room" or "war room") refers to a form of project management used in Asian companies (including Toyota) and is a component of lean manufacturing and in particular the Toyota Production System. https://en.wikipedia.org/wiki/Obeya

(Zietsma et al. 2002). Endorsement of trusted niche representatives furthermore facilitate the collective thinking (Zietsma et al. 2002).

As an outcome of the value stream mapping, Schulze et al. (2013) observe changed behavior and development of both individual and organizational level. Presenting the results to management in one case help management to gain insight into the complexity of engineering processes and further behavioral changes (Schulze et al. 2013). Value stream mapping result in organizational mechanisms ensuring routinized actions such as monthly improvement meetings, and specific measures for efficiency guiding improvements of work practices and interactions in the process (Schulze et al. 2013). However, one case discuss implementing key performance indicators measuring continuous improvements though the process team consider formal key performance indicators would be short-sighted (Schulze et al. 2013). Three out of four cases establish a dedicated room (Obeya) with value stream maps for continuing activities (Schulze et al. 2013). These cases exemplify how methods (in this case value stream mapping) can be institutionalized in daily work and lead further improvements of processes (Schulze et al. 2013). Following up on the cases show that the activities had been implemented and companies tailored the value stream mapping to their own use (Schulze et al. 2013). Solutions effectiveness for dealing with the organizational problem facilitate attention to future learning processes (Zietsma et al. 2002).

Institutionalizing learning process involves individual, group, and organizational levels as the companies in Schulze et al.'s (2013) cases take collective actions to change both actual product development processes as well as organizational structures and procedures. Management getting insights into processes and identified problems, plays a vital role in turning individual and group insights into action (Schulze et al. 2013).

4.3 Discussion of integration of new work practices

The purpose with this chapter was to identify activities that facilitate an organizational learning process for integrating new work practices into product realization and provide an answer for the third research question:

RQ3: What activities facilitate organizational learning processes in product realization?

I have identified activities that facilitate the four organizational learning processes Intuiting, Interpreting, Integrating and Institutionalizing. Furthermore, I have identified limitations that potentially can restrain organizational learning processes. Herewith I contribute with an extension to the 4I organizational learning framework shown in table 17. My primary focus in answering sub-question RQ3 is the group level integration. The integrating organizational learning process imply that both intuition/attending and interpretation/experimentation has taken place. After the Integration organization learning process new organizational practices are expected to be institutionalized throughout the organization.

17. Extending the original 4I framework with facilitating activities, limitations and further outcomes (*italic*). Additional processes (bold) origins from Zietsma et al. (2002)

Four learning processes on three levels in the 4I framework (original)			***Extension to the original 4I framework***
Level	***Process***	***Input/outcome***	***Facilitating activities***
Individual	Intuiting **/Attending**	Experiences Images Metaphors *Shared language*	*Communicate* *Reflection* *Challenging cognitive maps*
	Interpreting **/experimenting**	Language Cognitive maps Conversation/dialog *Shared understanding*	*Challenging cognitive maps* *Collective thinking* *Dialog* *Storytelling* *Visualization* *Inquiry* *Reflection*
Group	Integrating	Shared understandings Mutual adjustment Interactive systems *Insight/knowledge*	*Collective thinking* *Dialog* *Visualization* *Shared meaning* *Justification*
Organization	Institutionalizing	Routines Diagnostic systems Rules and procedures *Structures*	*Collective action* *Collective thinking* *Dialog* *Unlearning*

I extracted the activities and limitations from other case studies that apply the 4I framework. Therefore, further research is needed to verify these findings.

The identified activities and limitation are not exclusive and I expect that further studies can expand the list. In this dissertation, I apply the extended 4I framework for an analysis of data from applications of a CII-program in order to provide further explanations.

5 Continuous improvement and innovation programs

Continuous improvement and innovation of products emphasize that testing prototypes in early stages of the product development process allows learning from errors through experimentation (Cole 2002). Now consider a Continuous Improvement and Innovation (CII) program for a product, and a manufacturing enterprise the user applying a prototype of the CII-program. Similar to prototypes of products, I expect that applying prototypes of a CII-program generate insights about product realization processes for practitioners in addition to learnings about the CII-program for the program designer (in this case me). In the following, I seek to understand what practitioners and researchers can learn from prototyping a CII-program in a probe-and-learn process.

In this chapter, I first describe the development process of the CII-program based on prototyping in a probe-and-learn process. Then I study continuous improvement and innovation programs.

5.1 Prototyping a CII-program

Prototyping is a familiar practice in conventional product development, as is beta testing within software development (Cole 2002). Product development applies prototypes to initiate a dialogue with production about manufacturability and marketing to customers' needs (Cole 2002). Designers prototype product concepts, engineers prototype production designs, and software developers prototype programs—all in order to gain feedback from customers or other stakeholders at an early stage of development (Ulrich & Eppinger 2012). Testing prototypes with users then becomes an iterative and learning process for both designers and users (Ulrich & Eppinger 2012).

Cole (2002) proposed a probe-and-learn process for product development that comprises probe, test, evaluate, and learn (refine) as a way of speeding up Deming's Plan, Do, Check, Act (PDCA) model. The purpose of the probe-and-learn process is to receive instant feedback from users in product development (Cole 2002). Probe-and-learn is a way of approximating the product design (Cole 2002).

The Lean Start-up model within software development is a practical example of applying a probe-and-learn process. The Lean Start-up model follows a process where Ideas (then build), Code (and measure the result), Data (analyzing to learn) emphasizing the opportunities in getting input from users experience early in the development stage (Ries, 2011). Figure 9 illustrates the Lean Start-up model.

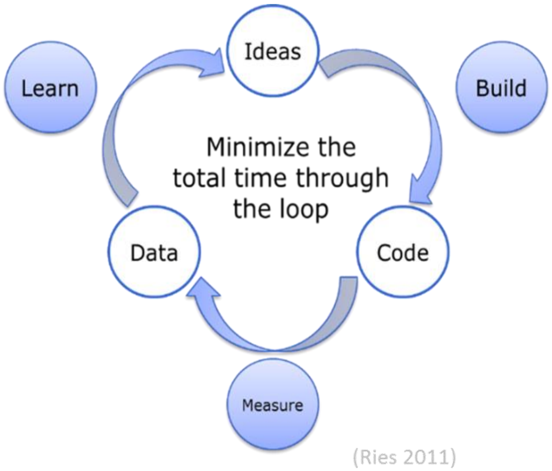


Figure 9. The Lean Stat-up model process working through loops of Ideas (then build), Code (and measure the result), Data (analyzing to learn).

5.2 Continuous improvement and innovation programs

The purpose of the CII-program is to support manufacturing enterprises that intend to solve problems in cross-functional work practices and integrate the solutions into product realization. The program builds on assumptions in organizational learning suggesting that organizations learn from experience and experimentation, from solving their own problems, and that solving these problems develop the organizational design (Argyris & Schon 1996). There are a few examples within literature that propose combining continuous improvement and innovation in a program. It remains a central task for practitioners and scholars to understand which organizational practices can be adopted to balance and maintain short-term efficiency and long-term innovation capabilities (Martini et al. 2013). Thus, Continuous Improvement and Innovation in this project refer to combining methods for incremental step-vice changes that can turn out to imply organizational innovations for product realization.

Continuous improvement is "… an organization-wide process of focused and sustained incremental change" (Bessant & Caffyn 1997). Bessant & Caffyn (1997) intend to increase participation from all groups of employees in innovation activities. The objective of a five-year action research program CIRCA (Continuous Improvement Research for Competitive Advantage) was to develop a basic methodology for implementing and maintaining continuous improvement (Bessant & Caffyn 1997). Bessant & Caffyn (1997) described five evolutionary stages in developing continuous improvement capabilities:

1) Background for continuous improvement with random problem solving
2) Structured continuous improvement with a use of formal problem solving processes
3) Goal oriented continuous improvement with monitoring and measuring systems
4) Proactive / empowered continuous improvement with high levels of experimentation
5) Full continuous improvement capability where everyone are actively involved

The fifth stage equals a learning organization (Bessant & Caffyn 1997). Boer and Gertsen (2003) define the concept of continuous innovation as "… the ongoing process of operating and improving existing, and developing and putting into use new configurations of products, market approaches, processes, technologies and competencies, organisation and management systems". CIMA (Euro-Australian co-operation centre for continuous Improvement and innovation Management) proposes a methodology that maps the current level of learning and knowledge management (strengths and weaknesses) as a basis for intra-firm and inter-firm comparison (Boer et al. 2001). Furthermore, Boer et al. (2001) provide guidelines for improving learning and knowledge generation processes in product innovation. The CIMA operationalized the model in questionnaires and developed a knowledge base comprising data from more than 80 companies (Boer et al. 2001).

Buckler (1996) proposed an individual learning process for continuous improvement and innovation. The learning process comprises ignorance, awareness, understanding, commitment, enactment, and reflection as elements (Buckler 1996). The premise for the program is leadership's attempt to enable a learning system supporting individuals' learning (Buckler 1996). As an important feature of his model, Buckler (1996) emphasize a progressive process where participants reflects on questions: "What have we learned?" and "How have we learned?"

More resent literature on implementation of or transformation to lean thinking such as a 4P model (philosophy, processes, people and partners, and problem-solving) (Liker 2004), however I do not aim at implementing or transforming organizations to lean thinking. Furthermore, literature do not address challenges in cross-functional work processes. In So far, I have found no examples in literature applying prototyping or probe-and-learn processes for developing and integrating continuous improvement and innovation programs into product realization processes or other meta-level development processes.

5.3 Inspiration for the process in a CII-program

Initially, I found inspiration for the process in the CII-program within design thinking and lean thinking. In the following, I will mention the most predominant inspirations.

Beckman & Barry (2007) model an innovation process moving through four stages: observation, frameworks, imperatives and solutions as shown in Figure 10. In Observation, participants use a variety of ethnographic observation methods to describe the context in which the problem is to be found (Beckman & Barry 2007). With Frameworks, participants code and visualize observations in different framings and reframing's to identify patters and ultimately develop a focus on what is most important to the customer or user (Beckman & Barry 2007). Participants then synthesize patterns into Imperatives that express the value proposition; a description of the tangible benefits customers will derive from using a product or service (Beckman & Barry 2007).

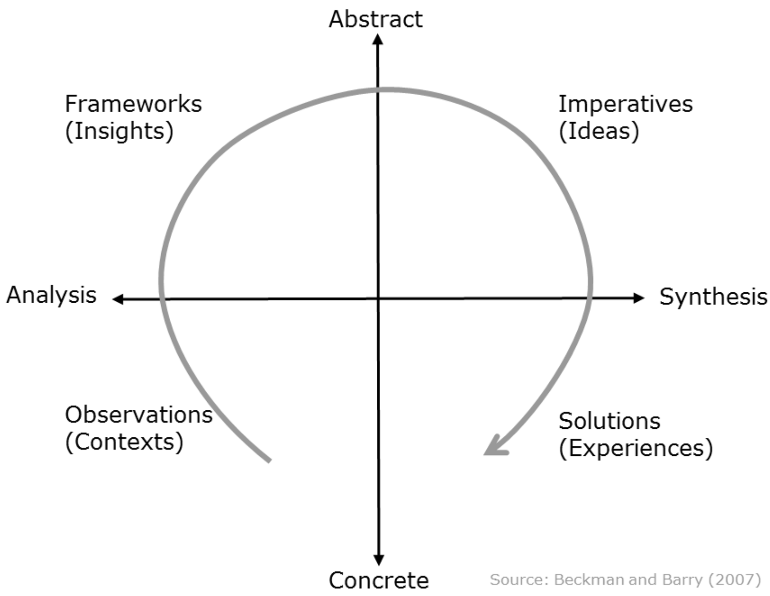


Figure 10. Model for an innovation learning process through Observations of contexts, Frameworks giving insights, Imperatives inspiring ideas, and Solutions generating experiences (Beckman & Barry 2007)

In design thinking, emphasize three phases: Inspiration, Ideation, and Implementation (Brown 2008). The process departs from exploring a business problem and prototyping solutions before implementation (Brown 2008). Lean product and process development used Look, Ask, Model, Discus, Act (LAMDA) based on Deming's Plan, Do, Check, Act (PDCA) model (Ward & Sobek 2014). These two iterative models shown in Figure 11 emphasized that designers and problem-solvers gradually learn from understanding customer needs and problems.

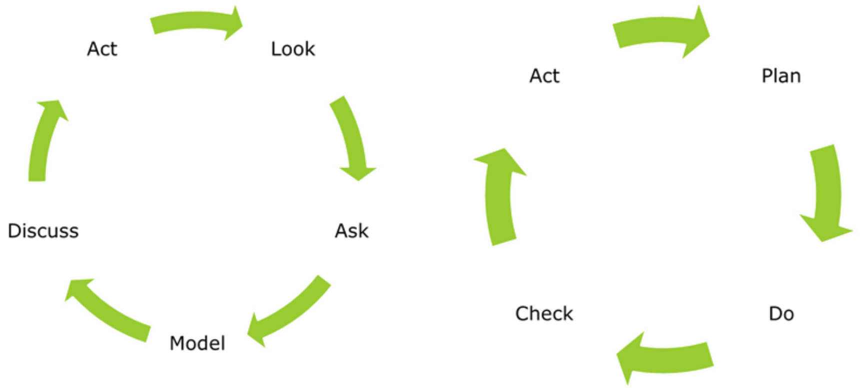


Figure 11. The Look, Ask, Model, Discus, Act (LAMDA) and Plan, Do, Check, Act (PDCA) models from Lean product and process development.

Innovation process (Beckman & Barry 2007), Design Thinking (Brown 2008), Lean product and process development (Ward & Sobek 2014), and the Lean Start-up model (Ries 2011) share a thorough exploration of problems and close interaction with context and users. These models inspired the four phases Clarify, Method, Lead and Share in the research design as well as the initial design of the CII-program.

Part III

In this third part of the dissertation, I present my methodological foundation and research design. The purpose is to provide transparency about underlying theoretical assumptions, applied theories, research methods and research design. This project collaborated with two manufacturing enterprises who kindly provided the study with data regarding real-life challenges in product realization. Applying a CII-program in two manufacturing enterprises provided the study with findings about integrating new organizational practices into product realization and about applying the CII-program in practice. Practitioners participating in applying the CII-program gained insights into their own product realization processes and their “theories-in-use.”

Chapter 6. Methodology provides transparency about the methodological foundation for research in this project. This chapter describes ontological and epistemological assumptions, academic fields, research methods and data collection methods applied in this project. The purpose of the chapter is to clarify the subjective phenomenological assumptions that serve as the basis for applying qualitative methods in this study. I based my theoretical framework on literature in the common denominator of operation management, organizational learning and knowledge management describing product realization processes, knowledge processes in product realization and organizational learning processes in creating new organizational practices thus improving product realization processes. In my empirical study, I applied a case study strategy, which explores application of the CII-program in two manufacturing enterprises. Data collection methods selected for this study include interviews, observations, interventions and field study to provide multiple sources of qualitative data about challenges in product realization and improvement of product realization processes.

Chapter 7. Research design describes a research design comprising four phases: (1) clarify challenges in product realization, (2) method development of the program, (3) lead in testing the program and (4) share and discuss with other companies. The purpose of this chapter is to provide transparency about planned and completed research activities. For this project, I applied an abductive strategy in order to clarify which cross-functional challenges the two manufacturing enterprises found most important. My intention was to engage the two manufacturing enterprises in solving problems that were relevant to them, thus targeting challenges of importance. Throughout the remaining study, I simultaneously explored empirical data and theoretical frameworks.

6 Methodology

The purpose of this chapter is to clarify my philosophical assumptions and choice of research methods in this study. I first describe the ontological and epistemological approaches of product realization applied in the study. Second, I present the intersection of operation management, organizational learning and knowledge management that provide the theoretical ground for this study. Third, I describe qualitative research and data collection methods applied in this study. Table 18 presents an overview of the applied methodology in this project.

18. Overview of applied methodology in this project

Purpose of the PhD project

- to develop and test a CII-program that integrates cross-functional work practices into product realization,
- to enhance understanding of organizational learning processes in cross-functional and multilevel settings within manufacturing.

Main research question:

How can manufacturers integrate new organizational practices into product realization processes?

Ontology and epistemology:

Subjective and phenomenological pragmatism

Research design:

A literature study for sub-question RQ1 defines a theoretical ground for an empirical case study for sub-question RQ2. The unit of analysis is product realization processes in manufacturing enterprises and describes the cross-functional challenges in product realization. Subsequently, a literature study for sub-question RQ3 defines a theoretical ground for an empirical case study for sub-question RQ4. The unit of analysis is the organizational learning process of integrating new organizational practices into daily product realization and addresses the previous identified cross-functional challenges in product realization.

Sub-questions	RQ1: What characterizes cross-functional work practices in product realization?	RQ2: What challenge cross-functional work practices in product realization in a medium sized Engineer-To-Order respectively a large Make-To-Stock manufacturing enterprise?	RQ3: What activities facilitate organizational learning processes in product realization?	RQ4: What activities facilitate integrating new organizational practices in product realization?
Theoretical framework	Exploration and exploitation challenges in manufacturing Cross-functional work practices and knowledge processes in product realization		Organizational learning processes in improving product realization Continuous improvement and innovation Program design	
Methods	Literature study	Two case studies	Literature study	Seven case studies
Data collection methods		Interviews Observations Field study		Interventions Observations Field study
Analysis		Explorative analysis of challenges in two cases.		Template analysis of organizational learning processes and related activities

The main purpose of this project was to develop and test a CII-program that integrates cross-functional work practices in product realization and to enhance understanding of organizational learning processes in cross-functional and multilevel settings within manufacturing. I applied an organizational learning perspective on product realization improvement and departed empirically from challenges in cross-functional work practices in product realization.

This study initially had a broad research topic, which became gradually focused over the course of the study. Finally, the research question of this project was "How can manufacturers integrate new organizational practices into product realization processes?" and was supported by the following four sub-questions:

RQ1: What characterizes cross-functional work practices in product realization?

RQ2: What challenge cross-functional work practices in product realization in a medium sized Engineer-To-Order respectively a large Make-To-Stock manufacturing enterprise?

RQ3: What activities facilitate organizational learning processes in product realization?

RQ4: What activities facilitate integrating new organizational practices in product realization?

For RQ1, I studied literature on cross-functional work practices in product realization that served as the theoretical ground for the following empirical study in RQ2. Then, for RQ2 I explored challenges related to cross-functional work practices in product realization in two case studies. For RQ3, I studied literature on organizational learning processes related to integrating new organizational practices into product realization. Finally, in order to answer RQ4 and the overall research question, I proposed a CII-program that integrated new cross-functional work practices into daily product realization.

For the empirical work, two appointed manufacturing enterprises were examined that were both experiencing challenges in cross-functional collaboration between engineering and production functions. These challenges led to recurring quality problems and delayed implementations of new products or processes (thus delaying product realization), which thereby reduced efficiency throughout the organization and caused frustration for organizational members. Quality issues and delays could also impair the customer experience of products and thereby affect manufacturing enterprises' competitiveness.

Research in this study created learning opportunities for organizational members across functions assigned by management representatives to solve specific problems in product realization processes and integrate new organizational practices into product realization. I chose to create these learning opportunities to provide insight for the practitioners as well as for myself as the researcher. Alternatively, I could have chosen to conduct a study describing existing practices or constructing artificial learning opportunities. However, my intention was to have an impact and learn about integrating new organizational practices into product realization.

6.1 Ontology and epistemology

In the following I describe the ontological and epistemological assumptions that were central to the research choices I made for this project. Ontological and epistemological assumptions explain how scholars understand the world and what scholars consider to be knowledge (Saunders et al. 2012). These assumptions influenced the way scholars formulate research questions and plan their studies (Saunders et al. 2012). Ontology comprises scholars' assumptions of what constitute facts and relates to objective or subjective perspectives (Saunders et al. 2012). To be objective implies that a scholar considers entities as external to the social context in which they exist (Saunders et al. 2012). To be subjective implies that a scholar considers observed phenomena inseparably from the social context (Saunders et al. 2012).

In this study, I adopted a subjective perspective and understood concepts such as learning as processes (Argyris & Schon 1996). Subsequently, I also considered knowledge as a subjective outcome of learning processes. However, I did not exclude objectivity, as learning also constitutes competencies and skills that are taught and proven in tests, and knowledge also constitutes assets that are transferable from one individual to another, e.g. using IT systems (Hislop 2013). In addition, my subjectivist stance influenced my perception of organizations, as I considered organizations as a collection of physical and social entities that also included social relations and processes. As such, I utilized a phenomenological research paradigm (Saunders et al. 2012) and perceived organizational learning as a phenomenon that I could observe (Crossan et al. 2011).

An epistemological approach describes scholars' criteria for what constitutes acceptable knowledge and depends on a scholar's philosophical position (Saunders et al. 2012). Scholars taking a positivistic position favor observable or objective data and seek causal relationships between factors in the data (Saunders et al. 2012). From a realist position, scholars sense reality and emphasize that objects have an existence independent of human thinking (Saunders et al. 2012). Finally, scholars taking an interpretivist position consider humans as social actors that interact with each other (Saunders et al. 2012). Interpretivists apply phenomenology to constantly make sense of the world (Saunders et al. 2012).

For this study, I took a pragmatic position implying that I favor concepts that support action (Saunders et al. 2012). A pragmatic position was in line with a practice-based perspective that I used to select the methods found most relevant for the study. I used a practice-based perspective on the researched topics of cross-functional work practices in product realization (RQ1 and RQ2) and integration of new organizational practices into product realization processes (RQ3 and RQ4). A practice-based perspective meant that I valued applicability in the empirical world (Hislop 2013; Saunders et al. 2012).

In addition to ontology and epistemology, axiology or choices in stages of research also reflect a scholars' values (Saunders et al. 2012). In other words, I took a pragmatic position that include applying qualitative data collection methods and interpreting qualitative data. My values have developed through years of working and learning and have influenced my role as researcher. When I preferred to research in collaboration with stakeholders in the project, I primarily took the role as process consultant (Schein 1999), because I wanted to respect stakeholders' choices in solving their own problems instead of taking it out of their hands. Had I taken the role as expert (Schein 1999), I would have told or taught them what to do and they would have missed an opportunity for learning. The choice to solve cross-functional challenges in practice also reflected my preference for learning in contrast to teaching.

6.2 Theoretical framework

Operation management, organizational learning and knowledge management are three academic fields informing the theoretical framework for this study. Illustrated in Figure 12 below, the common denominator of these three fields was the manufacturing context of product realization processes and the learning processes of integrating new organizational practices into product realization.

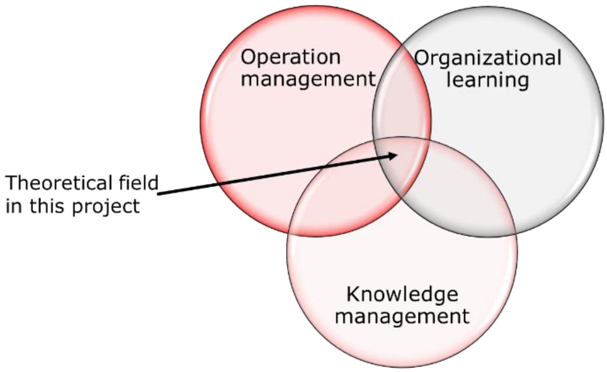


Figure 12. The theoretical framework in this study lies in the common denominator of operation management, organizational learning and knowledge management.

Literature within operational management defined product realization and related it to product development and production systems, thus characterizing cross-functional work processes in product realization. Literature within knowledge management described different types of knowledge processes in product realization. Operation management and knowledge management literature together provided perspectives on cross-functional work practices in product realization.

My primary aim was to understand the manufacturing context in which the challenges occurred. Therefore, I studied work practices such as procedures, relational interaction between people and knowledge processes related to product realization in manufacturing enterprises. The cross-functional challenges in product realization focused on workflow and structure, knowledge processes as well as horizontal and vertical collaboration. Then, a closer examination of knowledge processes emphasized relationships with novelty of knowledge.

My study then applied an organizational learning perspective on integrating new organizational practices into product realization. Literature within organizational learning defined organizational learning processes and described elements for organizational learning processes in cross-functional contexts. Literature on organizational learning processes thus characterized integration of new organizational practices in product realization.

My aim was to understand how organizations integrate learnings into new practices. Therefore, I studied activities and cross-functional behavior that support organizational learning processes such as inquiry and creation of collective meaning. I also aimed to determine the output from the processes in terms of new organizational practices and insights gained from applying the CII-program. The organizational learning processes emphasized facilitating activities such as reflection, dialogue, challenging cognitive maps, collective thinking and shared meaning that I incorporated into the CII-program.

In addition to continuous improvement and innovation, the development process in the CII-program relies on theories within operation management (Cole 2002) and organizational learning (Dixon 1994; Crossan et al. 1999). Both bodies of literature assume problem solving as a source of improvement and innovation for manufacturing enterprises. Furthermore, literature within operation management and organizational learning provided the study with examples of practices for continuous improvement and innovation in product realization contexts.

My aim was to develop a CII-program and understand how it worked in practice. Therefore, I applied a probe-and-learn process that relied on solving problems in close collaboration with users to generate learnings on early stages in a program-design process. I sought activities and criteria supporting organizational learning processes that were applicable to the design process as well as to the CII-program itself. The design criteria then directed the selection of activities and development of the CII-program.

6.3 Qualitative research methods

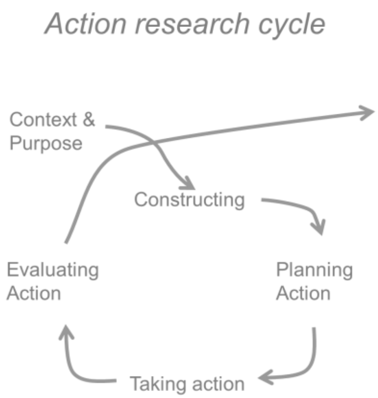
The choice of research methods was made based on practices within the theoretical framework mentioned in the previous section as well as my philosophical position. Scholars studying organizational learning processes in product realization apply both quantitative and qualitative methods (Jiménez-Jiménez & Sanz-Valle 2011; Vogel & Güttel 2012; Turner et al. 2013). The choice of whether to apply quantitative or qualitative research methods depends on the research philosophy and research question (Creswell 2014; Saunders et al. 2012). Quantitative research designs often rely on positivism and apply deductive approaches in order to study relationships between identified variables, such as collected in surveys (Karlsson 2009; Saunders et al. 2012). Researchers within organizational learning study antecedents and consequences in industrial contexts (see for example Gibson & Birkinshaw 2004; Jiménez-Jiménez & Sanz-Valle 2011). Within operation management literature scholars study relationships between conditional factors and continuous improvement (see for example Angelis & Fernandes 2012). In contrast, qualitative research designs often rely on interpretive philosophy to make sense of social actions and subjective meanings in real-life settings (Saunders et al. 2012). As such, qualitative studies provide in-depth knowledge and rich descriptions of the observed phenomena (Karlsson 2009; Saunders et al. 2012). Ingvaldsen and Rolfsen (2012) and Fundin and Elg (2010) exemplify qualitative research designs within the theoretical framework for this study. Furthermore, there are examples of researchers that use mixed methods, such as Johansson and Osterman (2017).

Collaboration between research and practice can be mutually beneficial and informative, as the researcher gains access to real-life data and practitioners gain access to applicable knowledge (Karlsson 2009; Ellström 2015). Collaborative research is an umbrella concept for action research, interactive research and participatory research (Ellström 2015). For example, Boer et al. (2001) applied collaborative research to develop their CIMA-methodology. Collaboration between research and practice can also take place as part of a case study. For example, Carlile (2004) applied case study research to develop his 3T framework.

My aim for this project was not only to develop a CII-program applicable to real-life challenges but also to integrate new organizational practices into product realization in two manufacturing enterprises. In the following I describe action research, collaborative research and case study research.

Action research

Action research enables a mutual learning process and a collaborative partnership between a researcher and an organization (Bradbury & Reason 2003). Action research provides a company with self-help capabilities while granting the researcher access to real-life data (Coghlan & Brannick 2014). Research activities are conducted in successive action research cycles, each of which comprise four steps of developing a construct, planning action, taking action and evaluating action leading to revising the construct and planning the next step (Coughlan & Coghlan 2002; Coghlan & Brannick 2014). Figure 13 illustrates an action research cycle, in which a company clarifies a problem to solve and gradually develops, refines and tests the program.



(Source: Coghlan & Brannick 2014)

Figure 13. Action research cycle of constructing, planning action, taking action and evaluating action (Coughlan & Coghlan 2002; Coghlan & Brannick 2014).

Action research is characterized by involving organizational members in diagnosing and solving assigned problems with the intention to conduct research with rather than on people (Bradbury & Reason 2003). Furthermore, action research is characterized by being research in action rather than about action (Bradbury & Reason 2003).

The conference paper in Appendix B exemplify describing research as action research.

Collaborative research

Collaborative research have two objectives that address purposes for both research and practice. The inclusion of two objectives entails a risk of emphasizing one objective at the expense of the other (Ellström 2015). Ellström (2015) offers a model of research intended to equally satisfy dual objectives of research and practice by dividing activities into two flows. One flow describes research activities within a research system, while the other describes activities involving the practice system (Ellström 2015). Figure 14 illustrates Ellström's (2015) research model.

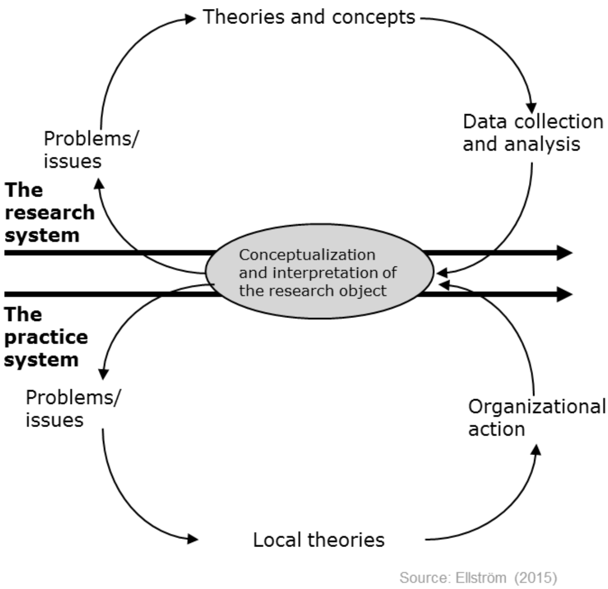


Figure 14. Research model integrating the research system and the practice system (Ellström 2015).

Ellström's (2015) research model is characterized by involving organizational members from the practice system, as with action research. However,

Describing this study as following Elström's research model:
The research system comprised a PhD project supervised by DTU Management Engineering, which was one out of five parallel and independent PhD projects in MADE work package 7 "The Future Manufacturing paradigm." The work package leader was a researcher at Copenhagen Business School who arranged half-year meetings with a steering committee. Appendix A1 provides more information about MADE. The practitioner system partly comprised both the work package steering committee and the two manufacturing enterprises included in this project. The steering committee followed the research projects and was given early feedback on their findings For this project, the task was formulated as: "improving efficiency and quality in product realization by supporting knowledge sharing across functions as part of daily operations." However, project stakeholders discussed and adjusted formulation of the task midway in the project. The suggested CII-program satisfies this research need from the practice system.

Ellström (2015) proposes that practitioners and researcher define and integrate tasks of conceptualization and interpretation of the research object.

Case study research

Case studies within operation management include descriptions of organizations, incidents or phenomena (Karlsson 2009). Case studies allow greater understanding the complexity of real-life organizational phenomena (Karlsson 2009) and provide in-depth insights for theory (Dubois & Gadde 2002; Saunders et al. 2012). Case study research can address physical as well as human aspects of organizational phenomena (Voss et al. 2011).

Case studies are useful for developing theory, new ideas and for testing theory (Dubois & Gadde 2002; Voss et al. 2011). Case studies are also useful for creating a construct pointing toward further research (Eisenhardt 1989; Eisenhardt & Graebner 2007). Research from case studies provides descriptions based on vast amounts of identified and collected data, which is time consuming and demands great care on validity when generalizing from cases (Eisenhardt & Graebner 2007; Voss et al. 2011). On the other hand, research could gain relevance and usability for practice by applying case study research (Voss et al. 2011).

Karlsson (2009) suggests that longitudinal field studies are a special type of case study research that implies several visits over a longer period. Longitudinal field studies provide real-time snapshots and require the researcher to remain and interact with the organization on a daily basis (Karlsson 2009). Within operation management, longitudinal case studies are useful for describing and explaining events in organizational change (Karlsson 2009).

Dominant scholars (Eisenhardt 1989; Eisenhardt & Graebner 2007; Yin 2009) within case study research offer useful tools and techniques that rely on replication logic and represent a linear and positivistic approach. Other scholars (Dubois & Gadde 2014) offer more non-linear and non-positivistic approaches to case research, such as Dubois and Gadde (2014) who distinguish themselves from positivistic scholars such as Eisenhardt and Yin.

Action research, collaborative study or case study research

I initially planned my research as action research. During the study, it was of outmost importance to me to base relationships with participants on mutual trust. Spending considerable hours and days over two and a half years has allowed me to become closely acquainted with the researched organizations and vice versa. Organizational members at mutual levels and across functions contributed to the CII-program design by taking part in and evaluating activities in the CII-program. Management representatives contributed by choosing a focus in the test by selecting design criteria and methods. Participants in the interventions influenced program design through suggestions of tools and methods and by evaluating the activities in each application of the CII-program. I used the metaphor "prototype" for the CII-program throughout the development process, making it apparent to participants that the CII-program was unfinished work.

In this study, I took the role of facilitator of activities and researcher documenting the events. As such, I was both a researcher exploring the applicability of prototyping in developing a CII-program and a designer developing and testing a CII-program. Scholars can question whether research for this study truly is action research, as I developed the program at home before applying prototypes. In hindsight, conducting workshops about the program design with direct contacts from the two companies could have been a way to overcome this implication. My consideration then becomes whether I could describe my method as collaborative research. However, the formulated task for the project was not a deliberate discussion between the steering committee and me as researcher. In hindsight, holding a deliberate discussion about the task, methods and purpose could have been helpful for the project. Instead, for this dissertation I have chosen to describe the applied method as a longitudinal case study.

Selection of manufacturing enterprises for case studies

The Manufacturing Academy of Denmark, MADE, assigned two manufacturing enterprises (hereafter named company A and company B) to this project, who had volunteered to participate in research that initially had a specified focus on organizational ambidexterity. These two facts meant that the selection of cases followed a non-probability sampling technique, where my task as researcher was to categorize whether company A and company B represented extreme cases, heterogeneous cases, homogeneous cases, critical cases, typical cases or theoretical cases (Saunders et al. 2012).

To understand similarities and differences between company A and company B, I used a classification of production systems proposed by Groover (2008). Production systems vary by type of product, production volume, product mix as well as their size Groover (2008). Table 19 lists definitions of production quantity, product variety, product complexity and part complexity parameters (Groover 2008).

19. Definitions of production quantity, product variety, product complexity and part complexity parameters (Groover 2008).

Parameter	***Definition***
Production quantities	"*Production quantity* refers to the number of units given part or product produced annually by the plant." Low: 1 to 100 units Medium: 100 to 10,000 units High: 10,000 to millions of units
Product variety	"*Product variety* refers to the different product designs or types that are produced in a plant."
Product complexity	"For an assembled product, one possible indicator of *product complexity* is its number of components – the more part, the more complex the product is."
Part complexity	"For a manufactured component, a possible measure of *part complexity* is the number of processing steps required to produce it."

The order decoupling point, as described in Chapter 2, additionally influences lead-time and frequency in product realization. Furthermore, the number of employees indicates the size of organizations. As shown in table 20, company A and company B differed in size (number of employees) and type of production system. In addition, company A and company B had different order decoupling points and subsequently different types of product realization processes.

20. Characteristic parameters for company A and company B

	Company A	*Company B*
Products	Pumps for OEM and own brand	Equipment for graphic industry
Number of employees	18,000	235
Production quantities	High	Low
Product variation	Medium	High
Product complexity	Medium	High
Order decoupling point	Make-to-stock	Engineer-to-order

However, company A and company B were not particularly outstanding among the population of manufacturing enterprises in Denmark. The cases were heterogeneous more than homogeneous, however they did not represent opposing contexts that could inform research on contradictory perspectives on product realization. Company A and company B could have otherwise represented critical cases especially rich in data enlightening the studied phenomenon (Crabtree & Miller 1999), or the cases could have particular importance for the research topic (Saunders et al. 2012). Cases could also have involved a theoretical sampling, where selection criteria were based on analysis of a larger pool of data (Crabtree & Miller 1999). However, company A and company B formed two typical cases for manufacturing enterprises in Denmark, representing one that is large make-to-stock and one that is medium-sized and engineer-to-order. Consequently, the case selection represents a purposive sampling (Saunders et al. 2012).

This project comprised seven units of analysis in seven case studies within company A and company B. Each of the case studies were limited to three to six months and the overall research took place over a period of approximately 2½ years. Studying product realization processes in a medium-sized and a large manufacturing enterprise made it possible to clarify differences in conditions for product realization (e.g. resources and competencies). Selecting multiple cases within the two manufacturing enterprises provided data about several applications of the CII-program.

6.4 Qualitative data collection

In this section, I present data collection methods applied in the case studies for this project, which provided me with qualitative data from interviews, observations, interventions and other field data. The various types of data collected for the case studies provided me with different organizational perspectives and enabled me to validate opinions stated by individual organizational members.

Interviews

A research interview conducted with one or more people is a purposeful conversation that can vary in degree of structure (Saunders et al. 2012). Types of interviews range from being highly structured with specific questions to semi-structured with open-ended questions to unstructured or in-depth interviews (Saunders et al. 2012). Moreover, scholars add standardization vs. non-standardization and focused vs. non-focus dimensions to interviews (Saunders et al. 2012). Highly structured interviews are useful for descriptive and explanatory studies (Saunders et al. 2012), while unstructured interviews on the other hand are useful for exploratory studies (Saunders et al. 2012).

One consequence of conducting interviews is that interviewees' subjective bias can be misleading (Alvesson 2003; Saunders et al. 2012). One way to address this issue could be to perform more interviews to provide more perspectives to the questions. However, the diversity of organizational agendas might be misleading as well (Alvesson 2003). Alvesson (2003) suggests that the interview situation is a social and linguistic situation which is not only a source of bias but also calls for a reflexive approach. In a reflexive approach, a researcher considers that the interviewee is in a non-routine situation, tries to understand the purpose of the situation, adopts a self-position, adapts to pressure and uncertainty, maintains self-esteem, develops a rationale for participating in the interview, represents through language and assumes that there is a discourse operating behind the scenes (Alvesson 2003). This means that a researcher reflects on different interpretations of the interview situation, the interviewee and the interview itself (Alvesson 2003). Building trust in the relation between the interviewer and the interviewee is emphasized as a way to address these limitations (Gummesson 2000).

This study applied semi-structured interviews to clarify cross-functional challenges from a management perspective. Conducting semi-structured interviews enabled me to explore and elaborate on the questions together with the interviewee, provided the interviewees with an opportunity to describe the company's challenges in their own words and allowed me to ask explorative questions to generate rich descriptions and explanations (Saunders et al. 2012). As the interviewees were unfamiliar with the organizational ambidexterity construct, I could not phrase the questions to include the word 'ambidextrous' (Alvesson 2003). Instead, I used broad and open-ended questions in order to avoid leading or misleading the interviewee from focusing on innovation and daily operations. In addition, my own introduction to the interviewees about the research project, purpose of the interviews and presentation of my background also framed the interviews and lead to interviewees' associations.

Observations

In the anthropological tradition, observations record actions and interactions between participants in real-life settings (Karlsson 2009). Scholars suggest that observations form an alternative method to gather evidence regarding a research object or phenomena (Voss et al. 2011). Schein (1999) described participant observation as the clinical method. Saunders et al. (2012) distinguish between qualitative participant observations, which emphasize the discovery of meanings in people's actions and interactions, and structured observations, which are quantitatively concerned with frequency of actions. Saunders et al. (2012) describe four types of participant observations (visualized in Figure 15): complete participant, complete observer, observer-as-participant and participant-as-observer.

Figure 15. Four types of participant observation describing the researcher's role (Saunders et al. 2012).

A researcher records different types of data during observations (Saunders et al. 2012). When observing meetings or work situations, a researcher notes primary observations of what happens and who said what (Saunders et al. 2012). However, researchers' notes are subjective statements and as such are secondary observations (Saunders et al. 2012). Moreover, experiential data reflect how the researcher experiences a particular situation, and contextual data relate to the physical setting of observed situations (Saunders et al. 2012). Implications of performing observations are subsequently highly related to bias and ethical issues (Saunders et al. 2012).

The purpose of observations in my study was to provide data about challenges in organizational members' daily work. By observing which problems organizational members were discussing on the shop floor and in offices, meetings and workshops, my intention was to become acquainted with the organizations and experience organizational challenges as they occurred in daily working life. While interviewing managers informed me about strategic intentions and manager's narratives explaining them, the purpose of the observations was to achieve a daily work perspective. For the sub-question RQ2, my position was primarily observer-as-participant, revealing my identity but only participating when participants asked me questions at a meeting. For the sub-question RQ4, I participated in the interventions applying the CII-program. In those situations, I took the position of participant-as-observer. I explicitly included primary observations, secondary observations, experiential data and contextual data in my notes to address limitations from doing observations.

Interventions

In operation management, interventions relate to clinical research and longitudinal field studies (Schein 1999; Karlsson 2009). Schein (1999) considers all types of inquiry and interaction within organizations as interventions, which also includes interviews and observations (Schein 1999; Karlsson 2009). Interventions are related to collaborative research and especially to action research (Coughlan & Coghlan 2002; Saunders et al. 2012). The purpose of collaborative research is to create knowledge for both practitioners and researchers and implies objectives for both (Karlsson 2009; Saunders et al. 2012).

In this study, I used the concept "interventions" to distinguish my observations from planned activities that were part of the CII-program. The purpose of the interventions was to construct a learning opportunity for solving problems regarding cross-functional work practices in product realization processes. Interaction with organizational members participating in the CII-program unavoidably and intentionally influenced the organization and its members. Therefore, my actions influenced data for these case studies. Section 7.7 examines research quality and discusses possible implications of participants' and researcher's bias.

Other field data

Besides interview and observations, I spent hours in offices and shop floors seeking information on boards and internal webpages in order to generate archival data regarding strategic targets, tactical plans, improvement activities, key performance indicator status-boards, production plans and organizational charts. I also met with managers and contact persons several times during my stays at the companies to negotiate access, plan activities, give feedback and share preliminary findings. All these different sources of field data supplemented statements from organizational members and served the purpose of data triangulation.

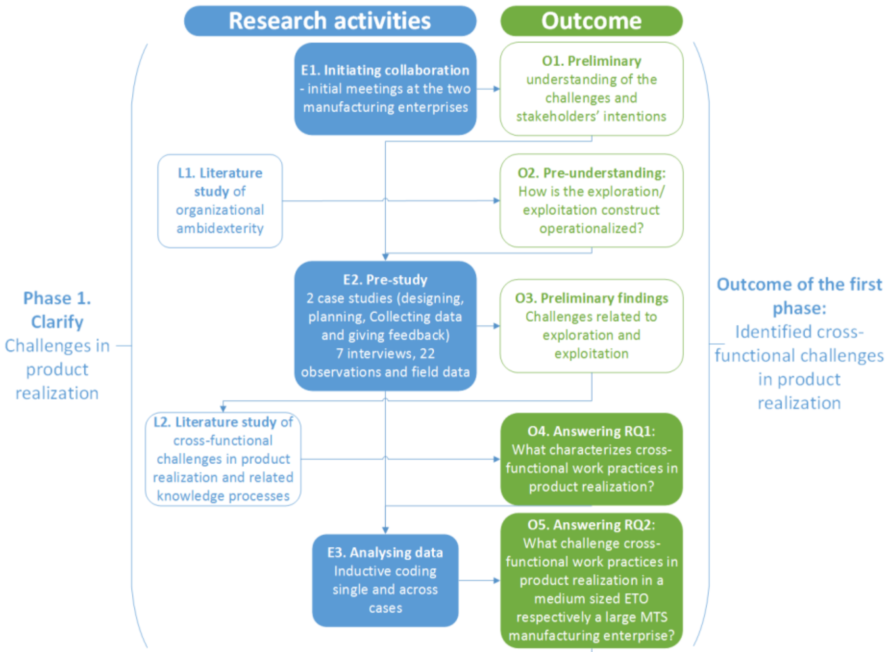
6.5 Summary

This project originated from a broad research topic. Therefore, I initiated an explorative study of the research topic to narrow the problem from a broad research topic to one or a few easily researchable examples. The study thereafter had an explanatory nature, as I developed and tested a CII-program to understand organizational learning processes in practice. A case study research design was useful within operation management for the purpose of developing theory, new ideas and testing whether specific theories and models actually apply to a phenomenon in the real world. On these grounds, a case study research design was applicable for developing a program in collaboration with two manufacturing enterprises.

7 Research design

The purpose of this chapter is to provide transparency about the research design in this study, which included an abductive strategy where I studied literature while completing empirical studies in two manufacturing enterprises. The research design illustrated in Figure 16 comprised four phases: (1) clarify challenges in product realization, (2) method development of the program, (3) lead in testing the program and (4) share and discuss with other companies.

In the following I first describe how I applied an abductive strategy by developing a theoretical framework while collecting and analyzing empirical data. Second, I describe the literature that provided me with a theoretical framework for the empirical studies. Then, in the following four sections I describe the planned and completed research activities in each of the four phases. Finally, I evaluate research quality in this study and discuss validity.



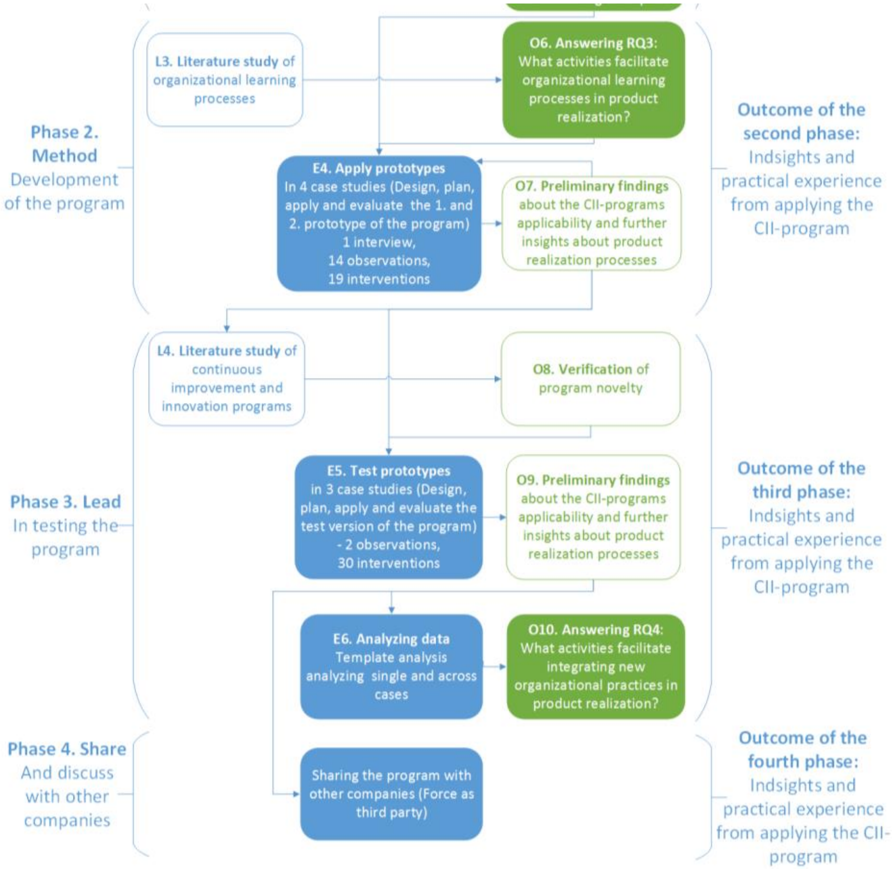


Figure 16. Research Design comprising four phases: (1) clarify challenges in product realization, (2) method development of the program, (3) lead in testing the program and (4) share and discuss with other companies.

Table 21 lists the data collection methods applied in the case studies, definitions of applied methods and types of data generated from applying these methods. Furthermore, table 21 relates data collection methods to sub-questions and describes the purpose of applying the data collection methods.

21. Data collecting methods applied in this project, their definitions, types of data and relation to the research questions			
Data collection methods	***Data repository***	***Research question***	***Research purpose***
Interviews	Recordings Transcriptions Personal notes	RQ2	Insight into cross-functional challenges from management's perspective.
Observations	Observation notes Personal notes	RQ2 (RQ4)	Insight into what cross-functional challenges other organizational members face as part of their daily work.
Interventions	Intervention diaries Observations Recordings Self-assessments Tools and materials Pictures Personal notes	RQ4	Construct a learning opportunity for solving knowledge sharing problems in product realization.
Other field data	Documents Factual data Questions for the factory Pictures Personal notes	RQ2, RQ4	Enrich the description of organizational context, development processes and challenges with factual data as well as informal conversations

To answer sub-question RQ2, I collected data from interviews with management representatives, observations in offices and shop floors and collected other field data that documented or provided additional information nuancing/specifying statements about cross-functional challenges in product realization. For sub-question RQ4, I used data generated in interventions where I applied the CII-program in the manufacturing enterprises.

7.1 Abductive strategy in research

In this section, I describe how I applied an abductive strategy to clarify which cross-functional challenges were found to be most important to company A and company B. My intention was to engage the two manufacturing enterprises in solving problems relevant to them, thus targeting challenges of importance. Throughout the remaining study, I alternated between using empirical data and theoretical frameworks.

An abductive approach to case studies is a way of adapting the theoretical world to the empirical world through mixing inductive and deductive approaches (Dubois & Gadde 2002). Dubois and Gadde (2002) suggest 'systematic combining' as a non-linear process of simultaneously developing a theoretical framework, doing empirical case studies and analyzing case data. The purpose of systematic combining is to refine existing theories more than to invent new ones (Dubois & Gadde 2002). Alternating between theoretical and empirical research activities enables scholars to expand their understandings of both (Dubois & Gadde 2002). Abductive case research departs from an analytical framework consisting of articulated preconceptions (Dubois & Gadde 2002). The case study then evolves through theoretically directing empirical data collection that subsequently directs further theoretical studies (Dubois & Gadde 2002). Dubois and Gadde (2002) present 'matching' and 'direction and redirection' as two processes to systematically combine theoretical and empirical studies. Matching is a process of matching theory to empirical reality, and direction and redirection is a process of applying multiple data sources to determine the direction and redirection of the study (Dubois & Gadde 2002). In practice, empirical data collected might for example not match the theoretical concepts and models, or the empirical conditions might change while performing case research with organizations over a longer period (Dubois & Gadde 2002). Stakeholders might change their priorities or positions within organizations, management might reorganize departments or even entire units and external conditions might change strategic focus. Such changes can close doors that are no longer relevant as well as open new ones (Dubois & Gadde 2002).

In this project, statements about flexibility/innovation and efficiency challenges from company A and company B were my point of departure. The first literature studies formed preconceptions about organizational ambidexterity (March 1991; Zimmermann et al. 2013; Lavie et al. 2010; Birkinshaw & Gupta 2013) and were empirically combined with my knowledge and experience about company A and company B as well as with the production context in general. Thereafter, I conducted further literature studies in parallel with my empirical studies on company A and company B. I studied product realization within operation management (Bellgran & Säfsten 2010; Dekkers et al. 2013; Lu & Botha 2006), related knowledge processes (Nonaka 1994; Carlile 2004; Foss et al. 2010; Xu et al. 2010; Boer et al. 2001) and organizational learning processes (Argyris & Schon 1996; Dixon 1994; Crossan et al. 1999).

I entered the two manufacturing enterprises with a preunderstanding of explorative and exploitative challenges in developing production systems while simultaneously securing stable and efficient processes. This explorative study revealed cross-functional challenges I then studied in the context of product realization processes. I subsequently turned to literature to study product realization and related knowledge processes across organizational functions. Based on these findings, I returned to an empirical study of challenges in the two manufacturing enterprises. I explored cross-functional challenges in product realization processes to identify problems that I could address with a CII-program.

The next part of the study applied a CII-program prescribing a method for solving problems selected among the previously identified challenges. I again applied an abductive approach in designing prototypes of a CII-program based on problem solving practices in organizational learning, lean thinking and design thinking. I then refined the prototypes based on empirical findings from applying the CII-program. For the final design criteria for the program, I searched for further explanations from the literature before testing the final version of the program. Finally, I analyzed data from applying the program.

Studying literature and the empirical context influenced my research question through gradual refinements. My initial research question was “How and under what circumstances can operation management develop ambidextrous capabilities in an organizational learning process?” As such, testing an organizational learning process was at the core of the project from the beginning. This first research question was broad and did not specify whether the development of ambidextrous capabilities regarded individual management capabilities or organizational design. In the middle of the project, I realized that the ambidextrous construct lacked substantial operationalization. The concept of “organizational ambidexterity” caused confusion regarding what I was working on and how organizational learning related to that. However, I found the concepts of exploration and exploitation as defined by March (1991) helpful in describing organizational learning behaviors. The final research question was then “How can new organizational practices be integrated in product realization processes?”

Even though the research design in Figure 16 illustrates a linear process, I conducted literary and empirical studies in parallel, so that the studies informed each other along the way. With that in mind, the following section first describes literature studies forming the theoretical framework and then subsequently describes research activities in the empirical studies.

7.2 Literature studies

In this section, I present the literature studies that formed the theoretical framework for this study. The literature studies changed focus as the empirical studies progressed, as mentioned previously. Table 22 lists the final literature studies informing the theoretical framework included in this dissertation.

22. Literature studies forming the theoretical framework for the studies

Research activities	***Purpose***	***Outcome***
Phase 1. Clarify Challenges in product realization		
L1. Study literature on exploration and exploitation	To understand how literature describes the challenges	**O2**. Theoretical background for exploration and exploitation
L2. Studying literature on cross-functional challenges in product realization	RQ1: What characterizes cross-functional work practices in product realization?	**O4.** Theoretical background describing Product realization characteristics in OM literature Characteristics: - Workflow and structures - Knowledge processes - Horizontal and vertical collaboration
Phase 2. Literature studies		
L3. Study literature on organizational learning processes	RQ3: What activities facilitate organizational learning processes in product realization?	**O6.** Selected papers reflect alone product development and not product realization
L4. Study literature on continuous improvement and innovation programs	To verify whether other researchers have made something similar	**O8.** No other programs combine lean and design thinking in solving problem in cross-functional development processes

I based L1 on a preliminary search for literature reviews that helped me generate ideas for a specific research topic (Saunders et al. 2012). I conducted the following L2, L3 and L4 as critical literature studies in a deductive approach where I subsequently drew comparisons to my empirical findings (Saunders et al. 2012). The literature review process formed a spiral, as I conducted searches, evaluated the literature and refined the search parameters (Saunders et al. 2012).

L1. Literature study on exploration and exploitation

Initially, my understanding of the ambidextrous construct shaped my empirical investigation of challenges, tensions or dilemmas in the two companies. I studied what the concepts of exploration and exploitation could explain about challenges in manufacturing enterprises. I based the literature study on existing research streams highlighted in literature reviews (Raisch & Birkinshaw 2008; Birkinshaw & Gupta 2013; Simsek 2009; Lavie et al. 2010) and a bibliometric analysis (Almahendra & Ambos 2015). My primary focus was to identify which capabilities characterize organizational ambidexterity.

O2. Outcome of the L1 literature study on exploration and exploitation

I found that literature on organizational ambidexterity and related capabilities lacked substantial operationalization. Therefore, I concluded that organizational ambidexterity was not relevant for describing cross-functional challenges in product realization. Furthermore, I found limited literature operationalizing organizational learning processes within organizational ambidexterity to support my development of a CII-program.

L2. Literature study on cross-functional challenges in product realization

For sub-question RQ1, I planned to study literature on operation management to identify characteristics for cross-functional work practices in product realization processes. This would provide me with a theoretical background to the context I was studying in the two manufacturing enterprises.

I found literature on Scopus based on the search criteria in table 23. I limited literature to journals and subjects to “business management and accounting” and “engineering.”

23. Concepts used for a literature review on RQ1: What characterizes cross-functional work practices in product realization?		
Product realization	OR Product and process development	AND Cross-functional
product and process development OR product realization	product development AND process development OR production development OR engineering OR production process OR manufacturing process	cross-functional OR cross function OR across functions OR cross boundary OR across boundaries OR across organizational boundaries OR boundary spanning OR inter-functional OR Interfunctional OR Intraorganizational OR intra-organizational OR Interdepartmental OR Intergroup OR inter-group
DOCTYPE (ar OR re) AND (LIMIT-TO (SRCTYPE , "j ")) AND (LIMIT-TO (SUBJAREA , "BUSI ") (SUBJAREA , "ENGI")) AND (LIMIT-TO (LANGUAGE , "English "))		

I reviewed titles of 53 papers excluding the following concepts: leader, leadership, human factor, marketing, market orientation, commercialization, strategic fit, strategic orientation, cross-company, supplier relationships, business networks, software development, telework, pharmaceutical industry, banking and information systems. I then limited the publication period to 2004 to 2016 before reviewing 16 abstracts and full papers. Finally, I included 9 papers in the literature study.

O4. Outcome of literature study on cross-functional work practices in product realization

The 9 papers included in the literature review are listed below in table 24. Only 4 of the 9 papers include the entire product realization process.

24. Papers included in the literature review			
Reference	***Product development***	***Process development***	***Production***
(Saunders et al. 2014)	X	Systems Engineering practices	Not included in data
(Vroom & Olieman 2011)	X	Industrial Engineering	Not included
(Valle & Vázquez-Bustelo 2009)	Respondents: NPD managers	not part of the survey	not part of the survey
(Rauniar et al. 2008)	Respondents: product development managers and team members	Mentioned in Framework	Mentioned in Framework
(Lu & Botha 2006)	X	X	X
(Kahn 2005)	Respondent	Respondent	Respondent
(Yasumoto & Fujimoto 2005)	X	?	Not represented in data
(Nagaraj 2004)	X	X	X
(Carlile 2004)	X	X	X

I analyzed the selected papers according to the Star-Model (Galbraith et al. 2002) to identify topics that characterize cross-functional work practices in product realization processes, as shown below in Figure 17.

	(Saunders et al. 2014)	(Vroom & Olieman 2011)	(Valle & Vázquez-Bustelo 2009)	(Rauniar et al. 2008)	(Lu & Botha 2006)	(Kahn 2005)	(Yasumoto & Fujimoto 2005)	(Nagaraj 2004)	(Carlile 2004)
Capabilities									
Strategic opportunity	X				X	X			
Affordability, cost efficiencies and quality	X		X	X	X				
New state-of-the-art technologies	X								
Superior or renewing products	X		X						
Faster time-to-market	X				X			X	
Shorter development cycles	X		X	X	X			X	
Find, select, share, create and challenge knowledge and information		X		X			X		
Existing knowledge management systems		X							
Avoid glitches				X					
Learn quickly				X					
Adaptive capabilities							X		
Innovations at the boundaries between disciplines or specializations									X
Structure									
Cross-functional integration	X		X		X		X	X	
Matrix organization	X								
Transition from in-house manufacturing to external sourcing	X								
Integrate suppliers	X			X	X				
Early involvement			X						
Multiple feedbacks			X					X	
Mechanisms that equalize status particularly enable collaboration						X			
Multi-level and multidisciplinary problem solving teams								X	
Processes									
Consulting colleagues instead of searching		X							
Concurrent work-flow / overlapping activities			X	X	X			X	
Simultaneous planning			X						
Transfer and shared knowledge and information				X				X	X
Modular design					X				
Early investment (or frontloading)					X		X		
Mutual support					X				
technology integration and separated technology development							X		
Frequent and structured reviews and prototyping								X	

	(Saunders et al. 2014)	(Vroom & Olieman 2011)	(Valle & Vázquez-Bustelo 2009)	(Rauniar et al. 2008)	(Lu & Botha 2006)	(Kahn 2005)	(Yasumoto & Fujimoto 2005)	(Nagaraj 2004)	(Carlile 2004)
People									
Engineer expertise competences	X	X							
Instilling and retaining corporate knowledge	X								
Corporate knowledge and training	X								
Teamwork towards common goals and solve problems			X	X	X		X		
Communication climate and conflict resolution					X				
Learning through experimentation					X				
Stationing multidisciplinary expertise together								X	
Empowerment of cross-functional ream members								X	
Translate knowledge									X
Rewards									
Community of designers add content		X							
Reducing ambiguity			X						
Development objectives					X	X	X		
Consistent focus on new product at all levels								X	
Transform knowledge									X

Figure 17. Topics characterizing cross-functional work practices in product realization.

Based on this analysis, I identified three overall themes:

a) Workflow and structures addressing cross-functional teams working in concurrent workflows with overlapping activities.
b) Managing knowledge processes across functional boundaries and knowledge boundaries (novelty).
c) Horizontal and vertical collaboration within and across teams and functions in product realization to negotiate ambiguous or conflicting goals.

These three themes were discussed in Chapter 2.

L3. Literature study on organizational learning processes

For the sub-question RQ3, I studied literature on organizational learning processes to identify possible characteristics. The concepts I used in the literature search are listed below in table 25.

25. Concepts used for a literature review on RQ3: What activities facilitate organizational learning processes in product realization?	
Organizational learning processes	***AND Product realization***
organizational learning process OR process of organizational learning OR explorative learning OR exploitative learning OR single-loop learning OR double-loop learning OR trial-and-error learning OR inferential learning OR vicarious learning OR generative learning OR transformative learning OR learning from experience OR experiential learning OR learning from experimentation OR experimental learning OR learning by doing	product development OR process development OR product and process development OR production development OR product realization OR new product introduction OR industrialization OR manufacturing engineering OR manufacturing process production process
DOCTYPE (ar OR re) AND (LIMIT-TO (SRCTYPE , "j ")) AND (LIMIT-TO (SUBJAREA , "BUSI ") (SUBJAREA , "ENGI")) AND (LIMIT-TO (LANGUAGE , "English ")) Period: 2000 – 2016	

I reviewed titles of 88 papers excluding the following concepts: management practices, strategy change, inter firm, marketing, education, simulation, environmental analyses, forecasting, joint ventures, medical equipment, foodservice, computational model, market orientation, surgical simulations, partnership, Supply-chain, software, marketplace, export, customers, pharmaceutical, virtual worlds, surgical, economics, suppliers, political, medicine, students, chemical, medical, commercialization, microcredit, teaching, course, brand,

I then reviewed 17 abstracts and read 11 full papers.

O6. Outcome of literature study on organizational learning processes

Figure 18 lists the selected papers that characterize organizational learning processes in product realization.

	(Österlund & Lovén 2005)	(Akgun et al. 2006)	(Lampela & Karkkainen 2008)	(De Houwer 2009)	(Liu et al. 2011)	(Li 2013)	(Lee et al. 2013)	(Li & Huang 2013)	(Mulotte 2014)	(Gadotti Martins et al. 2015)	(Anand et al. 2016)
organizational learning process	X	X									
process of organizational learning											
explorative learning					X	X	X	X			
exploitative learning					X	X	X	X			
single-loop learning					X						
double-loop learning					X						
trial-and-error learning											
inferential learning											
vicarious learning											
generative learning			X		X						
transformative learning											
learning from experience					X		X		X		X
experiential learning								X			
learning from experimentation											
experimental learning					X						
learning by doing										X	

Figure 18. Selected papers characterizing organizational learning processes in product realization

The selected papers reflected alone product development and not product realization. Instead, I searched for empirical applications of the 4I framework (Crossan et al. 1999). As an outcome, I identified activities that facilitate organizational learning processes.

L4. Literature study on continuous improvement and innovation programs

To ensure novelty of the CII-program, I reviewed literature on continuous improvement and innovation programs and other types of development programs related to product realization. Table 26 shows the concepts I chose for this purpose.

26. Concepts used for literature search on CII-programs			
Product realization	***OR Product and process development***	***AND Cross-functional***	***AND Continuous improvement and innovation***
product and process development OR product realization	product development AND process development OR production development OR engineering OR production process OR manufacturing process	cross-functional OR cross function OR across functions OR cross boundary OR across boundaries OR across organizational boundaries OR boundary spanning OR inter-functional OR Interfunctional OR Intraorganizational OR intra-organizational OR Interdepartmental OR Intergroup OR inter-group OR	continuous improvement OR continuous innovation OR continuous improvement and innovation OR continuous innovation and improvement OR organizational innovation OR problem solving OR problem-solving OR
DOCTYPE (ar OR re) AND (LIMIT-TO (SRCTYPE , "j ")) AND (LIMIT-TO (SUBJAREA , "BUSI ") (SUBJAREA , "ENGI")) AND (LIMIT-TO (LANGUAGE , "English ")) Period: 2006 - 2016			

I reviewed titles of 19 papers excluding the following concepts: conflict management, IT-systems, computer-based, modelling, software, services, inter-organizational, eco-design and bio technology.

I then reviewed 12 abstracts and 7 full papers.

O8. Literature study on continuous improvement and innovation programs
None of the papers covered dimensions of continuous improvement and innovation in product realization processes.

Summary

These four literature studies provided me with a theoretical framework based on operation management, knowledge management and organizational learning. The first literature study (L1) described organizational ambidexterity as lacking operationalization for studying product realization in production systems. The second literature study (L2) pointed towards differences in development practices, inefficient knowledge flows and misaligned coordination as characterizing challenges in product realization. The outcome of literature study L2 provided an answer to sub-question RQ2. In the following description of phase 1 of clarifying challenges in product realization, I describe how the first literature study formed my preliminary understandings in the first studies of exploration and exploitation in company A and company B. Subsequently, literature study L2 enabled me to clarify the empirical context of work processes and knowledge processes in product realization.

Moving into the prescriptive part of my study, the third literature study (L3) clarified activities for a CII-program addressing the previously identified challenges in product realization. Literature study L3 characterized organizational learning processes when integrating new organizational practices into product realization and hereby answered sub-question RQ3. This part of the theoretical framework supported my formulation of design criteria for the CII-program. Phase 2. Method developing the program comprises the subsequent application of prototypes of the CII-program in company A and company B.

Literature study L3 found a limited number of programs that included both continuous improvement and innovation and furthermore that none of these programs considered organizational learning processes. This resulted in three tests of the CII-program during phase 3. Lead testing the program. In addition, I analyzed data generated from the program application in phases 2 and 3. Finally, phase 4. Share and discuss the program comprises dissemination of my findings to other companies. In the following four sections, I describe the planned and completed empirical research activities of the four phases.

7.3 Phase 1. Clarify challenges in product realization

The purpose of the first phase in this research project was to clarify the challenges in two manufacturing enterprises. This was an explorative study where I drew from preliminary understandings of exploration and exploitation from literature study L1 and characteristics of cross-functional challenges in product realization from literature study L2. In the following section, I describe the planned and completed empirical research activities in Phase 1. Clarify challenges in product realization.

Planned activities for Phase 1. Clarify Challenges in product realization

I planned three activities for phase 1. First, I initiated collaboration with the two manufacturing enterprises assigned for this study. Second, I conducted a preliminary study on challenges related to exploration and exploitation in manufacturing. Third, I analyzed the collected data to understand what caused the challenges and hereby answer sub-question RQ2. Table 27 contains a list of the research activities as well as the purpose and expected outcome of the activities.

27. Planned research activities in Phase 1 Clarify Challenges in product realization

Activities	*Purpose*	*Research activities*	*Expected outcome*
Phase 1. Clarify Challenges in product realization			
E1. Initiating collaboration with company A and company B	Organize point of contact, clarify unit of analysis and align expectations and get a first impression of the challenges	Collecting observation notes from meetings with primary contacts in company A and company B	**O1.** Preliminary understanding of the challenges and stakeholder's intentions
E2. Preliminary study of challenges related to exploration and exploitation in cases	**RQ0:** What are the (exploration and exploitation) challenges in manufacturing?	a) Selecting data collection methods b) Planning data collection c) Collecting data (Interviews, observations, field data) d) Giving feedback to management	**O3.** Two case studies describing the challenges related to exploration and exploitation in two manufacturing enterprises
E3. Analyzing challenges in product realization	**RQ2:** What are challenges to cross-functional work practices in product realization in a medium sized Engineer-To-Order and a large Make-To-Stock manufacturing enterprise?	I. Coding challenges and other issues II. Grouping the codes into types III. Relationships between the codes	**O5.** Causes or part of the problem solving process as an answer to RQ2.

E1. Initiating collaboration with company A and company B

The purpose of the meetings with companies A and B was to establish a trustful relationship with the stakeholders from the beginning. I wanted to ensure their commitment to aligning expectations for our collaboration and acquire a first impression on challenges of relevance for this project. Furthermore, I wanted to identify management representatives to whom I could present my preliminary findings and who then could decide and authorize the following activities in the project. By placing the decision in the hands of management, I wanted to ensure relevance, commitment and resources for the following activities. Therefore, I established meetings with appointed contact persons within the first month of the project.

E2. Preliminary study of challenges in company A and company B

My plan for the first part of the research was to conduct semi-structured interviews with key informants, visit workplaces and participate in meetings to gain insights into which challenges the organizational members were discussing and trying to solve as part of their daily work. The activity comprised four steps in which I first a) constructed data collection methods, b) planned data collection with contact persons within the two cases, c) completed the activities and d) provided feedback for management. I chose few key informants from management positions representing production and development functions. It was my intention to achieve an overview of the strategic and tactical intentions of the companies. However, due to the bias of more or less political agendas, I was also interested in what was present in daily work situations. Therefore, I supplemented interviews with observations to achieve insight into the daily work challenges in both production and engineering/technology functions. The plan was to present the preliminary observations from the case studies to management representatives so that they could choose which challenges would be a relevant focus for the study. As an outcome of this preliminary study, I planned to describe the organizational design in company A and company B according to the Star-Model (Galbraith et al. 2002).

Completed activities for clarifying challenges in product realization

In the following section, I describe how the research activities were completed. Table 28 lists the completed research activities and outcomes.

28. Completed research activities in Phase 1. Clarify Challenges in product realization

Activities	*Purpose*	*Research activities*	*Outcome*
Phase 1. Clarify Challenges in product realization			
E1. Initiating collaboration with company A and company B	Organize point of contact, clarify unit of analysis and align expectations and get a first impression of the challenges	Meetings in both companies	**O1.** Company A. Plan to study the Electronics factory and Technology Company B. Plan to study Engineering and Assembly
E2. Preliminary study of challenges related to exploration and exploitation in cases	**RQ0:** What are the (exploration and exploitation) challenges in manufacturing	a) Constructing interview guide and paradigms for observation notes and questions in production b) Planning interviews and observations at meetings and work places c) Collecting data by interviewing, observing meetings and d) Giving feedback to management teams	**O3. Case study A1** Challenges: · Organizational divide in product realization · Resources Knowledge sharing/feedback processes
			O3. Case study B1 Challenge: · Resources · Knowledge sharing/feedback processes · Different demands in business units Focus for both cases: => Cross functional knowledge sharing
E3. Analyzing challenges in product realization	**RQ2:** What are challenges to cross-functional work practices in product realization in a medium sized Engineer-To-Order and a large Make-To-Stock manufacturing enterprise?	I. Coding challenges and other issues II. Grouping the codes into types III. Relationships between the codes	**O5.** Causes to cross-functional challenges in product realization: · Different work practices disturb the product realization work flow · Insufficient knowledge sharing limits the ability to learn from experience =>Learning across functions is not integrated into daily product realization processes.

E1. Initiating collaboration with Company A and Company B

I visited the two case companies several times over a period from February to August 2015 following an introductory meeting with the technology director, a person internal responsible for MADE and lean manager in case company A and the CEO and lean manager in case company B. Short resumes of the meetings were included in the data collection.

O1. Outcome of initiating collaboration with company A and company B

As an outcome of these first two meetings, I gained insight into the technology director and the CEO's motivation and expectations for collaboration in the project. I was appointed the electronics factory and technology functions for the study in company A and engineering and assembly functions in company B. The technology director and the CEO identified the two lean managers as my direct contact persons for the project. Subsequently, the two lean managers introduced me to the organization and helped me find relevant people to interview and places to perform my observations for the following studies. Furthermore, the lean managers were available for clarification, arranging activities and discussing preliminary findings. In company A, I planned to follow a scheduled series of workshops for the technology management team and provide them feedback from the preliminary studies. In company B, it was clear that the management team of CEO, finance director, production manager and engineering manager would provide authorization and receive feedback from the studies.

E2. Preliminary study of challenges in company A and company B

After the first meetings with the companies, I prepared the first data collection and constructed an interview guide and paradigms for taking notes when observing and asking questions in production. The next section describes the applied data collection methods. I planned the following research activities together with the two appointed contact persons.

In company A, I interviewed the operation manager at the appointed factory, the lean director representing lean management development and the technology director representing technology development functions. The technology management team in company A had arranged a series of workshops with the purpose of formulating the company's future production system. As this topic was relevant to my initial research question, I negotiated and was authorized access to these workshops as an observer. I collected data about the challenges in developing the production system by observing these workshops. At the end of the final workshop, I presented my preliminary observations and discussed my observations with the management team.

In parallel, I observed engineering designers in company A while sitting in the technology office and formally discussed their challenges related to innovation and efficiency. A designer showed me a small meeting room with boards for key performance indicators and action plans. Observations were followed by interviews with the technology director and lean director. The lean manager introduced me to the electronics factory, where I participated in different daily meetings and interviewed the operation manager. Various supervisors and lean managers at the factory shared thoughts with me about challenges related to innovation and efficiency in the factory and showed me boards with key performance indicators and action plans. During the visit in the factory, I asked questions about what problems they were or were not discussing at the daily meetings.

In company B, the lean manager introduced me to production and I observed their daily meetings. I also participated in a weekly meeting with project managers in engineering and performed additional observations in the engineering offices. As company B had four business units with different types of projects, the lean manager and I discussed which business units I could focus on. My first choice was a rather new business unit that, unlike the others, produces series of orders to stock for a large customer. Furthermore, the assembly was situated at a separate facility with separate engineering functions. Unfortunately, the lean manager and I had to eliminate this choice due to a decline in orders. Instead, we suggested to the management team that the focus would be on another business unit with a series of customized orders. In parallel with these investigations, I interviewed four members of the management team comprising the CEO, finance director, production manager and engineering manager. As key informants, these four managers represented the key functions in the organization, as the CEO was responsible for sales. I presented the preliminary findings for the management team who then chose a topic and place for further investigations.

O3. Outcome of the preliminary study of challenges for company A and company B

In company A, the technology management team's purpose of the workshops was to formulate the future production system. The output from these workshops was a comprehensive description of the elements in the production system. As an outcome of my preliminary studies, I identified challenges regarding a structural organizational divide, resource availability and competencies as well as knowledge sharing and feedback processes in product realization.

In company B, the study revealed a number of challenges hampering learning from experience in cross-functional processes at the cost of lead-time, quality and productivity as well as innovation opportunities (or novelty). These challenges related to product realization include resource planning, knowledge sharing and feedback processes as well as differing demands in business units. The management team chose knowledge sharing across customized projects for the following activities.

In the remaining part of the project, I focused on product realization as a process spanning functions that literature on ambidextrous organizational design describes as having explorative (product and production development) and exploitative (production) purposes. Furthermore, I chose to focus on cross-functional work practices when applying the CII-program in phases 2 and 3.

Data collection in Phase 1. Clarify Challenges in product realization

Table 29 includes a short description of case studies A1 and B1. In both cases, data collection activities comprised observations at workshops, workplaces and meetings and semi-structured interviews.

29. Case descriptions for Phase 1. Clarify challenges		
	Case A1	***Case B1***
Case period	February to August 2015	February to June 2015
Functions	-Technology -Lean Electronics factory	-Engineering Production
Participants	-Technology management team, -Operations manager Lean manager and lean director	-Management team -Project managers Production supervisors
Situations	-Daily meetings in electronics factory -Workshops with technology management team Workplaces in production and technology	-Daily meetings in production -Meetings with project managers Workplaces in production and engineering
Data collection Activities	3 interviews 4 workshop observations 6 workplace observations 1 meeting observations 3 status meetings	4 interviews 8 workplace observations 3 meeting observations 1 status meeting
Types of data	-Transcribed interviews -Observation notes -Questions to the production Personal notes	-Transcribed interviews -Observation notes -Questions to the production Personal notes

In the following section, I describe the different types of data collected for case studies A1 and B1.

Semi-structured interviews

To clarify challenges in cross-functional processes from management's perspective, I applied semi-structured interviews with a limited number of questions inviting managers at two levels (director and manager) to discuss which challenges they faced in the company and in their department. I planned to use the same interview guide for all interviews, adding a few clarifications to two interviews in case A1. The interview guide in Figure 19 shows the translated questions for the semi-structured interviews.

Questions:
What do you see as the biggest challenge for (company name) at this time?
Why is it a challenge?
What does it mean for your area of responsibility?
What do you do to solve it?
What is the relationship with (company name) strategy?
Is there anything you would like to ask me?

Figure 19. Questions used in semi-structured interviews (translated from Danish).

The last question was especially useful, as the interviewees kept talking for 5 to 10 minutes about subjects adjacent to the framed topic. Subsequently, I gained valuable information about challenges that stimulated the interviewees' engagement.

Observations

My plan was to supplement interviews with observations at various meetings and workplaces in engineering and production in order to collect data on cross-functional challenges in daily work practices. To structure my notes from observations, I planned to use a paradigm with a "left hand column" separating my own reflections from the observed actions (Argyris & Schon 1996). A "left hand column" is a simple tool of separating an observer's thoughts and feelings from observational notes into different columns (Argyris & Schon 1996). In the example (with Danish text) shown in Figure 20, I noted how people were sitting or were otherwise situated in the room in the first column, objective actions and body language in the second column, atmosphere and interpersonal dynamics in the third column and my own reflections and feelings in the fourth column. The first two columns were objective and the following two columns were subjective including my interpretations of what I observed. Taking notes on how people were sitting (first column) helped me remember names of who said or did what. The objective actions and body language (second column) comprised the primary data that I was collecting. As I could not note everything at all times, I tried to ensure that I noted all topics, though not in detail covering all statements. In the third column, I noted preliminary interpretations regarding the atmosphere and interpersonal dynamics to aid their separation from my own momentary reflections (column four). These subjective data assisted my openness to unspoken tension or challenges.

Dato og klokken	d. 20. august 2015 9.24 – 12.51		
Observatør	Christina Villefrance Møller		
Beskrivelse af fysiske ramme	**Projektlokale for konstruktion**		
Personer til stede	Christina Villefrance Møller og Jesper, Martin, Torben og Klaus		
Personer /grupper	**Objektive begivenheder** **Kropssprog**	**Atmosfære** **Dynamik**	**Egne refleksioner** **Modoverføringsfølelser**
Der er 6 borde i lokalet. De fire personer, der er tilstede sidder over for hinanden i en gruppe. Jeg sidder/står ved et ekstra ledigt bord. Overfor mig er der en plads tilhørende en anden Jesper. Man kommer ind i lokalet via et andet lokale med konstruktører. En anden dør er ind til Morten konstruktionschefen. Dørene er åbne.	Jeg har fået anvist pladsen af Klaus, der er projektleder. En projektleder kommer ind til Morten. Han har behov for en ekstra ressource. Morten spørger, om det kan være fra mandag. En anden Dennis kommer og går ind til Morten og de lukker døren. 9.30 går Klaus, Jesper og Martin til møde med Rockwool som vil fortælle om varmeisolering. De havde forud talt om, hvad mødet gik ud på. Jesper havde ikke fået indkaldelsen: "Jeg er ikke på de fine lister".	De fire sidder med to skærme hver. En med tegningen og en med et skema (egenskaber) på den anden. De taler ikke meget sammen.	Klaus virker venlig og imødekommende, da jeg kommer ind og hilser på ham. Med de bemærkninger, jeg havde fået fra Martin, havde jeg ventet en mere fjendtlig modtagelse. Efter at have fået min kaffe og tændt computeren hilser jeg også på de øvrige i rummet.
	Torben spørger mig, hvor lang tid, jeg skal være her. Jeg svarer, i dag og ellers ca. en gang om		

Figure 20. An example of observational notes (in Danish), where I noted how people sat or were otherwise situated in the room in the first column, objective actions and body language in the second column, atmosphere and interpersonal dynamics in the third column and my own reflections and feelings in the fourth column.

The subjective and interpretive nature of observations urged me to consider my own role and reflections as including bias and therefore urged me to make them as transparent as possible. Furthermore, there were ethical implications to performing observations, as I might hear or see issues challenging the confidence built with the organizational members in the two case companies. I discuss these implications in Section 7.7.

Field data

For case studies A1 and B1, I collected field data describing the organizational structure, action plans and objectives (key performance indicators). Furthermore, I applied a paradigm with a few questions scoping my attention to problems discussed during brief daily huddles (usually 15 to 30 minutes) in production. These questions about the factory (translated from Danish) were:

- What are they talking about?
- Do the problems lie within their own powers?
- What issues do they not talk about?
- What gives me reason to think there's a problem?
- What do they do about issues raised?
- Are they talking about improvement suggestions?
- Are there indications of implemented improvements?
- What is improved?
- Can they implement improvements themselves?

Participating in daily huddles in production provides a brief snapshot. However, data from the huddles supplement interviews and observations in the sense that I might add operationalized nuances to identified challenges.

E3. Analyzing data from case studies A1 and B1

The purpose of the preliminary case studies was to provide data for analyzing cross-functional challenges in product realization. I expected the analysis to provide me with an answer to sub-question RQ2. For the analysis, I planned to apply an open code approach in three steps:

I. I would first code challenges and other topics brought up in interviews, field notes and observations.
II. I would then group the codes into themes
III. Finally, I would link the themes together to identify challenges

I selected codes based on the respondents ‘own words, which is described as ‘in vivo coding’ by Miles et al. (2014). I coded paragraphs with more than one code to provide different categories, such as who mentioned what challenges in relation to what type of activities. I used NVivo as CAQDAS (Computer

Assisted Qualitative Data Analysis Software) to support coding and analyzing data.

O5. Outcome of analyzing data from case studies A1 and B1

I initiated the coding in case B1 applied an open coding approach to the two cases and consolidated the codes across the interviews, observation notes and field notes. I then grouped the identified codes into eight themes. Two themes described stakeholders and business areas that I coded in order to be able to track which type of business and stakeholders the respondents were discussing (as shown below in table 30).

30. Two themes (stakeholders and business area) and codes applied in case B1	
Theme	***Code level 1***
Stakeholders (Interessenter)	Managers (Ledere) Project managers (Projektledere) Employees (Medarbejder) Designer (Konstruktører) Production (Produktionen) Customers (Kunder) Other companies(Andre virksomheder) Sales (Salg) Engineering department (Konstruktionsafdeling) Other in-house functions (Andre funktioner i huset) Suppliers (Underleverandører) Competitors (Konkurrenter) Researcher at SDU (Forsker på SDU) Board (Bestyrelsen) Strategic partner (Strategisk partner)
Business area (Forretningsområder)	Orders and projects (Ordrer og projekter) Machines (Maskiner) Ancillary Digital Standard products and batch production (Standardprodukter og Serieproduktion) Solution Products (Produkter) Key Line Large and small projects (store og små projekter) webshop Service Upgrading (Opgradere)

The next theme contains possible actions mentioned by the respondents, which were divided into internal actions, knowledge, daily work and project model (as shown below in table 31).

31. The theme action opportunities and codes applied in case B1.

Theme	*Code level 1*	*Code level 2*
Action opportunities (Handlemuligheder)	Internal actions (Interne tiltag)	Trim (Trimme) Standardization (Standardisering) Change (Forandringer) Lean - agility Improvements (Forbedringer) Degree of automation (Automationsgrad) Outsourcing (købe produktion ude) Gold, silver and bronze (Guld, sølg og bronze) Implement – roll out (Implementere - rulle ud) Reduce production (Skære produktion fra) Smartest way (Smarteste måde) Integrations (Integrationer) Solve problems (Løse problemer)
	Knowledge (Viden)	Information Share knowledge (Dele viden) Save knowledge (gemme viden) Retrieve knowledge (Hente viden) Have some knowledge (Ha' noget viden) Where it works (Hvor virker det) Outside information (Information udefra) SAP
	Daily work (Dagligt arbejde)	Follow-up (Opfølgning) Work routines (Arbejdsrutiner) Customize (Kundetilpasse)
	Project model (Projektmodel)	Estimating hours (Estimere timer) Order horizon (Ordrehorisont) Timeline (Tidsplan) Assessment (Auditere) Evaluation meeting (Evalueringsmøde)

The fourth theme described relations among the stakeholders, which were further divided into ‘understand,’ a concept mentioned frequently in the interviews; ‘interactions,’ where respondents described what happened in relations between stakeholders; and ‘reaction’ which was mentioned in relation to interactions between relations (as shown below in table 32).

32. The theme relations and codes applied in case B1		
Theme	***Code level 1***	***Code level 2***
Relations (Relationer)	Understand (Forstå)	Understand others (Forstå andre) Understand company B(Forstå B) Understand change (Forstå forandring) Understand customers (Forstå kunder) Understand decision (Forstå beslutning) Self-understanding (Selvforståelse) Cheese dome (osteklokke) Foreseeable (Overskueligt) Background (Baggrunden)
	Interaction (Interaktion)	Dialogue (Dialog) Collaboration (Samarbejde) Competition (Konkurrence) Contribution (Bidrag) Negotiation (Forhandling) Learning (Læring) Coordinate (Koordinere) Focal point (Omdrejningspunkt)
	Reaction (Reaktion)	Important (Væsentligt) Exciting (Spændende) Explorative (Undersøgende) Recognition (Anerkendelse) Resistance (Modstand) Fear (Frygt) Decision paralysis (Beslutningslammelse) Commitment

The fifth theme relates to capabilities divided into capacities and competencies. The theme capacities was divided into human resources, which contained a third level of codes and production set-up. Competencies were divided into 'good at,' technique, functionality, education and understand the machine (as shown below in table 33).

33. The theme Capability and codes applied in case B1			
Theme	***Code level 1***	***Code level 2***	***Code level 3***
Capability (Kapabilitet)	Capacity (Kapacitet)	Human resources (Menneskelige ressourcer)	Manning (Bemanding) Recruitment (Rekruttering) Lay-off (Afskedige) Levelling (Udjævning) Time pressure (Tidspres) Work hours (Arbejdstid) Enough labor (Arbejdskraft nok) Time consumption (Tidsforbrug) Journeys (Rejser) Stress
		Production set-up (Produktionssetup)	
	Competencies (Kompetencer)	Good at (Dygtig til) Technique (Teknik) Functionality (Funktionalitet) Education (Uddannelse) Understand the machine (Forstå maskinen)	

The final three themes describe results and strategy. Results are divided into six different concepts related to frequently used measures and a ‘be connected’ concept that was used for describing relationships between different measures. First of all, the code ‘challenge’ had its own group that was used to mark all challenges mentioned in data. Then the strategy group is divided into action (setting targets, analyzing, balancing, action plans and strategic change), innovation (and development), values, flexibility, risk, investments and differentiation (as shown below in table 34).

34. The themes challenge, results, strategy and codes applied in case B1		
Theme	***Code level 1***	***Code level 2***
Challenge (Udfordring)		
Results (Resultater)	Sales and turnover (salg og omsætning) Price (Prisen) Security of delivery (Leveringssikkerhed) Delivery time (Leveringstid) Quality (Kvalitet) Earnings (Indtjening) Contribution ratio (Dækningsgrad) Connected (Hænge sammen)	
	Costs (Omkostninger)	Waste (Spild) Production output (Produktions output) Equipment efficiency (Oppetid) Sub-optimizing (Suboptimering)
Strategy (Strategi)	Actions (Aktiv handling)	Objectives (Målsætninger) Analyze (Analysere) Fine balance (Balancegang) Action plans (Handlingsplaner) Change strategy (Ændre strategi)
	Innovation	Development (Udvikling)
	Values (Værdier) Flexibility (Fleksibilitet) Risk (Risiko) Investment (Investering) Differentiate (Differenciere)	

Creation of these groups enabled matrix analysis of selected groups with ‘challenge.’ Results of the analysis are shown in Chapter 10.

For case A1, I initially applied the same set of codes developed in case B1 though with adjustment by adding new codes. Similar to the process in case B1, I first coded the interviews and consolidated the codes across the interviews, observation notes and field notes. In case A1, I identified eight similar themes, although the content of the themes varied as shown in the following table 35, table 35, table 36 and table 37.

35. The themes stakeholders, business area, action opportunities and codes applied in case A1.

Theme	***Code level 1***	***Code level 2***
Stakeholders (Interessenter)	Managers (Ledere) Technology Lean managers (Lean konsulenter) Other in-house functions (Andre funktioner i huset) Employees (Medarbejder) Other companies (Andre virksomheder) Suppliers (Underleverandører) Customers (Kunder) Competitors (Konkurrenter) Sales (Salg)	
	Production (Produktionen)	Electronics factory (Elektronikfabrikken) Sensor factory (Sensorfabrikken) Composite factory (Komprosit fabrikken) Other factories (Andre fabrikker)
Business areas (Forretningsområder)	New products (Nye produkter) Products (Produkter)	
Action opportunities (Handlemuligheder)	Internal actions (Interne tiltag)	Lean - SE Projects (Projekter) Improvements (Forbedringer) More simple (Mere simpelt) Implement – roll out (Implementere - rulle ud) Solve problems (Løse problemer) Degree of Automation (Automationsgrad) Move factory (Flytte fabrik) Change (Forandringer) Standardization (Standardisering) Trim (Trimme) Integration (Integrationer)
	Daily work (Dagligt arbejde)	Work routines (Arbejdsrutiner) Daily operations (Daglig drift) Ramp-up Follow-up (Opfølgning) Plan and planning (Plan og planlægning) Test of new products (Test af nye produkter) Disturbances (Forstyrrelser)

Table 35 (continued)

	Structured process (Struktureret process)	
	Knowledge (Viden)	IT-system Simulation tool (Simuleringsværktøj) Information Share knowledge (Dele viden) Have some knowledge (Ha' noget viden) Save knowledge (gemme viden) Retrieve knowledge (Hente viden) Outside information (Information udefra)
	Many things happening (Sker mange ting)	

36. Theme relations and codes applied in case A1

Theme	Code level 1	Code level 2
Relations (Relationer)	Organization (Organisation)	Organizational structure (Organisationsstruktur) Agendas (Dagsordener) Guiding principles Organizational culture (Organisationskultur) Interfaces (Grænseflader) Cohesion (Sammenhængskraft)
	Interaction (Interaktion)	Dialogue (Dialog) Matching of expectations (Forventningsafstemning) Competition (Konkurrence) Collaboration (Samarbejde) Learning (Læring) Involvement (Involvering) Contribution (Bidrag) Coordinate (Koordinere) Negotiation (Forhandling) Focal point (Omdrejningspunkt)
	Understand (Forstå)	Understand others (Forstå andre) Understand the task (Forstå opgaven) Understand company A (Forstå A) Foreseeable (Overskueligt)
	Reaction (Reaktion)	Tensions (Gnidninger) Decision paralysis (Beslutningslammelse) Recognition (Anerkendelse) Commitment Motivation Resistance (Modstand)

37. Theme capability and codes applied in case A1

Theme	*Code level 1*	*Code level 2*	*Code level 3*
Capability (Kapabilitet)	Capacity (kapacitet)	Human resources (Menneskelige ressourcer)	Manning (Bemanding) Working hours (Arbejdstid) Time consumption (Tidsforbrug) Work place (Arbejdspladser) Hiring (Ansættelse)
		Production equipment (Produktionsudstyr) Production set-up (Produktionssetup) Way of working (måden at arbejde på)	
	Competencies (Kompetencer)	Technology (Teknologi) Good at (Dygtig til) Education (Uddannelse) Understand the machine (Forstå maskinen) Functionality (Funktionalitet)	

38. Theme challenges, results, strategy and codes applied in case A1		
Theme	Code level 1	Code level 2
Challenge (Udfordring)		
Results (Resultater)	Connected (Hænge sammen) Quality (Kvalitet) Security of delivery (Leveringssikkerhed) Safety (Sikkerhed) Earnings (Indtjening) Achieve target (Komme i mål) Benchmark Speed of implementation (Implementeringshastighed) Accuracy (Træfsikkerhed) Broadness (Rummelighed)	
	Costs (Omkostninger)	Equipment efficiency (Oppetid) Productivity (Produktivitet) Waste (Spild)
Strategy (Strategi)	Action (Aktiv handling)	Action plans (Handlingsplaner) Objectives (Målsætninger) Strategic direction (Strategisk retning) Priorities and choices (Prioritering og valg) Analyze (analysere)
	Innovation	Development (Udvikling)
	Flexibility (Fleksibilitet) Risk (Risiko) Differentiate (Differenciere)	

Subsequently, I identified challenges related to cross-functional work practices in product realization processes in both companies. The challenges in the two companies diverged due to different order decoupling points in product realization processes. I present the results of the analysis in Chapter 10.

7.4 Phase 2. Method developing the program

The purpose of the second phase of the study was to develop and test a cross-functional learning program that improved knowledge sharing in product realization processes. My decision to develop and test a program was based on the assumption that organizational members can learn from their own experiences and solve their own problems.

Planned research activities in Phase 2. Method Developing the program

In phase 2, I planned to apply prototypes of the CII-program to both company A and company B, as listed below in table 39.

39. Planned research activities in Phase 2. Method Developing the program

Activities	*Purpose*	*Research activities*	*Expected outcome*
Phase 2. Method Developing the program			
E4. Apply prototypes in Company A and Company B	To study the application of the first prototype	Designing the program Planning application of the program Appling the program (Observations, Interventions, field data) Evaluating and giving feedback to management These activities were repeated twice.	**O7.** Observed issues in applying the program

E4. Apply a prototype of the CII-program in the two case companies

The activity comprised four steps: designing the program, planning application of the program, applying the program as well as evaluating the program together with the participants and providing feedback to management.

For the first applications of the CII-program, I envisaged a simple process in which participants contribute to clarifying and solving the problems as well as in choosing methods. Figure 21 visualizes the planned process.

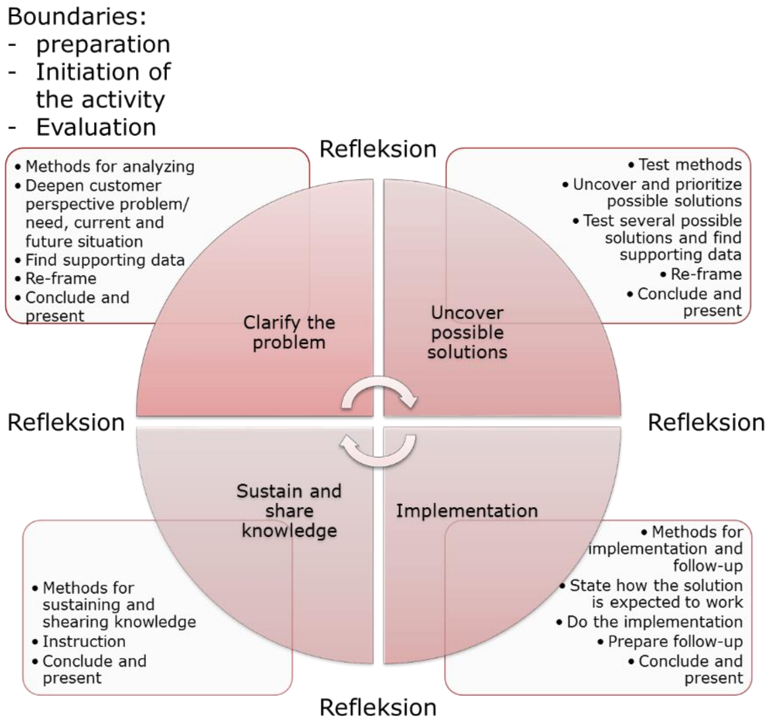


Figure 21. Illustration of the program used as the first prototype of the CII-program.

The activity plan includes formulating hypotheses, expected results and methods for measuring effect. I would first share the plan with an appointed manager and then with the participants. The first step would then include three 30-minute problem-solving sessions as part of a working day (morning, lunchtime and afternoon). The focus on problem solving would be the first (clarify the problem) and second (uncover possible solutions) quadrants in the model in Figure 21. My aim was to plan the timeframe so that the participants could integrate the activities into their daily work. In the second step, I planned a workshop of 2 – 3 hours focusing on the third (implementation) and fourth (sustain and share knowledge) quadrants in the program. Then, a third step would include the manager's report on his or her experiences to peer managers. A fourth step would begin a new cycle going through all four quadrants with a new problem and would occur during parts of the day on three or four days. Furthermore, the plan was to evaluate the problem-solving process and CII-program in order to gain insight into the outcome suggest possible next steps. After evaluating the activities, I would report the results to the management team in order to engage them in an inquiry regarding the problem and possible solutions. I then would expect the management team to consider a next step to solving a specific problem. This process was planned to be repeated twice in both company A and company B.

Completed research activities in Phase 2. Method Developing the program

The planned application of prototypes of the CII-program was completed as listed below in table 40.

40. Completed research activities in Phase 2. Method Developing the program			
Activities	***Purpose***	***Research activities***	***Outcome***
Phase 2. Method Developing the CII-program			
Phase 2. Applying the first prototype of the CII-program			
E4. Case A2 Production line in the Electronics factory	To understand cross-functional collaboration and problem solving in daily work	a) Designing observations b) Planning observations c) Observing break downs and challenge (Observations, Interventions, field data) d) Giving feedback to a local lean manager	**O7. Case A2** Observed issues in learning from experience: - there was learning objectives but no feedback loop - diverse attendance and intense focus but unclear prevention
E4. Case B2 Apply the prototype in Engineer-to-order	To study the application of the first prototype in an Engineer-to-order process	a) Design the program b) Plan application of the program c) Apply the program (Observations, Interventions, field data) d) Evaluating and giving feedback to production management	**O7. Case B2** Observed issues in applying the program: - limited tests of facts - limited exploration of alternative opportunities Suggestions for sharing knowledge within a project (implemented a board)
Phase 2. B Applying the second prototype of the CII-program			
E4. Case A3 Flow of controllers	To study the problem-solving process in a flow of controllers	a) Adjust the program b) Plan application of the program c) Apply the program (Observations, Interventions, field data) d) Feedback to management	**O7. Case A3** Observed issues in learning from experience: Observed issues in the applied problem solving methods
E4. Case B3 Apply the prototype in Engineer-to-order	To study the application of the second prototype in an Engineer-to-order process	a) Design the program b) Plan application of the program c) Apply the program (Observations, Interventions, field data) d) Feedback to management	**O7. Case B3** Deepened understanding of knowledge sharing problems from one project to the next Observed issues in applying the program

Phase 2. Applying the first prototype of the CII-program

E4 Case A2 Production line in the Electronics factory

In case A2, I had not yet gained access to apply a prototype of the program. I therefore continued my observations by focusing on two related production lines (MGE2-GEMS) in the electronics factory. At the MGE2-GEMS production lines, I observed a "challenge" on the GEMS line and four breakdown meetings on the MGE2 line. In the "challenge," a local lean manager, a facilitator on the production line and a supervisor responsible for the two production lines tested the GEMS line for 24 hours. I followed up on the "challenge" in an interview with the local lean manager to explore the outcome. In addition, I observed four breakdown meetings on the MGE2 production line, two on the same day in January 2016 and two on successive days in March 2016. The supervisor led the meetings that included several people across functions, such as a facilitator from the production line, an experienced operator, a maintenance manager, a production planner, a lean manager, specialists in soldering and technicians. The purpose of the breakdown meetings was to get the production line up and running again. Furthermore, I observed daily meetings and workplaces related to the two production lines.

O7. Outcome of Case A2 Production line in the Electronics factory

My preliminary observations from the "challenge" was that the learning objectives for the activity were made clear by the local lean manager and production supervisor. Participants identified and listed several problems, but there was no feedback loop to activity plans on boards or other continuous improvement activities. A diverse group of organizational members that represented different functions attended the breakdown meetings and were intensely focused on getting the line up and running again. However, it was unclear to me whether further activities were initiated to determine the root cause and whether similar breakdowns were prevented.

E4. Case B2 Apply the first prototype in Engineer-to-order

In case B2, a project group consisting of a project manager and three engineering designers applied a first prototype of the program for developing Engineer-To-Order processes in recurring projects for a specific customer. The project manager aimed to improve knowledge sharing about critical design issues within the project team, allowing them to work more efficiently and use less time for the design work. I adapted the first prototype of the CII-program to the specific problem and planned the process together with the project manager at a meeting. The prototype of the program consisted of five 30-minute meetings in the project office dispersed over two days within two weeks held to clarify the problems of which knowledge they needed to share. I encouraged them to invite others outside the group, such as an assembly team leader and engineering manager, to give their perspectives on the issue. A month later, the participants followed up on the identified problems by designing a board for sharing key information during a 90-minute workshop. After three months, the project group evaluated the interventions in a one-hour workshop. The project manager for the next series of interventions participated in the evaluation workshop. Additionally, the project manager and a member of the project group performed a self-assessment of the process. At the time of evaluation, two of the four members of the project group had left the company. The project manager presented findings at a regular meeting for other project managers. A one-hour standing meeting provided the management team with a report on findings.

O7. Outcome of Case B2 Apply the prototype in Engineer-To-Order

The interventions resulted in a board for sharing knowledge on the current project. I observed that time constraints in the engineer-to-order process made the designers cut corners in their design work. Furthermore, the time constraints left limited time for the designers to improve their own work practices.

Phase 2. B Applying the second prototype of the CII-program

E4. Case A3 Flow of controllers

In case A3, I had the opportunity to participate in a series of meetings aimed at solving problems in the flow between MGE2/GEMS production lines and the technician who analyzed prints failing in tests on the production lines. The technician reported directly to the production line supervisor, though for safety reasons they sat in an area with other technicians reporting to other supervisors. I did not follow the steps in the CII-program, as the participants applied a problem-solving process accustomed at the factory. In the beginning, a group of two facilitators from MGE2/GEMS and the technician facilitated the meetings themselves with support from a local lean manager. I primarily participated by asking questions. Later, the lean manager was more instructive and facilitated the problem-solving process following the structured method as customary in the company. The group met three times for about an hour over a period of one and a half months. A month later, the group evaluated the implemented solutions together with the supervisor.

O7. Outcome of Case A3 Flow of controllers

As an observation, I saw that the problem-solving activity primarily focused on delivering and implementing solutions and comprised insufficient exploration of root causes and limited exploration of alternative solutions. The participants were unable to verify the effect of implemented solutions with data. Furthermore, the handover between the local lean manager and the production line supervisor was unclear.

E4. Case B3 Apply the second prototype in Engineer-to-order

In case B3, I applied a revised prototype of the CII-program on another Engineer-To-Order process delivering a customized project to a customer. The project manager aimed at reducing recurring deviations in equipment design causing quality issues in assembly. I prepared the project manager for the CII-program in a similar way as in case B2 by adding a short resume of our arrangements. The lean manager participated in this preparatory meeting, during which I used a large A0 as a storyboard hanging in the assembly for the program activities. Application of the CII-program involved a small group: the project manager, lean manager and two team leaders from assembly. The group consulted the quality manager to clarify issues related to the quality system. This time, the group held five brief meetings (12 to 50 minutes) on the shop floor on three days spread out over a period of two months. The group evaluated the findings three months later, and I presented their observations to the management team together with the lean manager.

O7. Outcome of case B3 applying the prototype in in Engineer-to-order

Participants highlighted two tracks of main issues to preventing recurring deviations in subsequent projects. First, they questioned whether assembly actually register all deviations rather than just correcting the errors they find. It became obvious that not all technicians found it worth the trouble to file a registration in the IT-system. In their experience, designers do not correct the errors anyway, which was the second issue. Both issues were tested in reality, with the results showing that in the actual project, assembly did register the expected amount of deviations and designers did take action on them. Furthermore, overlapping projects caused delays in corrections when blueprints for a project were copied before the first project was finished in assembly.

Data collection in Phase 2. Method Developing the program

Table 41 includes a short description of case studies A2, A3, B2 and B3 applying prototypes of the CII-program. The collected data comprised intervention diaries, observational notes, personal notes and self-evaluations.

41. Case descriptions for Phase 2. Method Developing the program

Applying the first prototype		
	Case A2	**Case B2**
Case period	November 2015 to March 2016	August 2015 to February 2016
Participating (?) functions	Production line in the electronics factory	- Engineer-To-Order project team
Participants	Production supervisor, lean manager, operators (how many?	Project manager, project team
Problem in focus	- Breakdown on the production line Challenge the production lines' productivity	Sharing knowledge about critical design issues
Situations and activities	- Daily meetings on the production line - Ad hoc meetings at the production line Workplaces by the production line	- Problem solving meetings in engineering Workplaces in production and engineering
Steps in the program	- Prepare Clarify the gap	- Prepare - Clarify the gap - Design solutions - (Implement) Evaluate
Data collection methods	5 workplace observations 1 interview 5 status meeting observations	3 workplace observations 3 meetings (participating) 4 status meetings 8 program activities
Types of data	- Observational notes - Personal notes Intervention diary	- Observational notes - Personal notes - Intervention diary Self-evaluation

Table 41 (continued)		
Applying the second prototype		
	Case A3	**Case B3**
Case period	March to October 2016	March to September 2016
Participating (?) functions	Analysis function in the electronics factory	- Engineer-To-Order project team
Participants	Production supervisor, lean manager, 2 operators, 1 technician	Project manager, assembly team leader, lean manager
Problem in focus	Flow of controllers failed in test between the production line and the analysis function	Recurring deviation from one project to the next
Situations and activities	- Problem solving meetings in production Workplaces by the production line and in analysis	- Problem solving meetings in production Workplaces in production and Engineering
Steps in the program	- Prepare - Clarify the gap - Design solutions - Implement Evaluate	- Prepare - Clarify the gap - (Design solutions) Evaluate
Data collection methods	4 program activity observations 2 status meeting observations	3 meetings (participating) 2 status meeting 7 program activities
Types of data	- Observational notes - Personal notes - Intervention diary Self-evaluation	- Observational notes - Personal notes - Intervention diary Self-evaluation

Intervention diary

The intervention diary was a short resume of the activities that I shared with the project manager and production supervisor for verification. An example is shown in Figure 22. It was only possible to audio-record activities that took place in meeting rooms such as evaluations and meetings with management teams. Activities on the shop-floor were not audio-recorded.

Projekt/aktivitet: 73457 + 73558 SCA Malaysia

Opgave: Del viden om kritiske konstruktioner

Mål: I sidste tilsvarende projekt blev der brugt 1000 konstruktionstimer for meget. Dette skal reduceres.

Dato: 1. oktober 2015 Kl. 11. 20 – 11.50

Deltagere: Klaus (projektleder), Torben (konstruktionsansvarlig), Jesper og Martin
Christina (forsker)

Resumé:
Klaus fortæller, der er hængt projektplan med roller og ansvarsfordeling samt tidsplan med timeopfølgning op. Roller og ansvarsfordelingen gør at teamet får nogle af de opgaver, der ellers ligger hos projektlederen.
Christina spørger til, hvad der er sket siden sidst: Torben har været i gang med at bryde projektet ned i opgaver for at få et overblik. Jesper og Martin har hovedsageligt arbejdet med andre projekter.
Antallet af tegninger er ikke gjort op og Christina opfordrer til at lave et væddemål om hvem, der kommer tættest på.
Der har ikke været holdt daglige viden delingsmøder endnu. Viden deles hovedsageligt ad hoc hen over bordet.
Årsagen er, at der er meget travlt lige nu, så derfor er der en tendens til at hver koncentrerer sig om sit. De projekter, der ellers er afleveret forstyrrer stadig. Der kommer spørgsmål, som skal besvares og rettelser, der skal laves. Det giver anledning til at tale om at ordningen med at sidde ude i produktionen når montagen foregår. Det er ikke sket i det seneste projekt. Det nuværende projekt er 6 uger forsinket. Klaus vil gerne have at denne ordning tages op når den næste maskine skal monteres. Der er lidt blandede holdninger til at sidde ude hos montørerne og arbejde.

Billeder:

Refleksion:

Figure 22. Example of an intervention diary in case B (in Danish).

7.5 Phase 3. Lead testing the program

The purpose of the third phase of the study was to test a refined version of the CII-program. The test of the program comprised problem-solving activities, chronicle workshops, meetings with management and observations. The objective of applying the CII-program was to solve problems related to cross-functional work practices in product realization processes.

Planned research activities in Phase 3. Lead Testing the program

In phase 3, I planned to test a refined version of the CII-program in both company A and company B as listed below in table 42.

42. Planned research activities in Phase 3. Lead Testing the program

Activities	Purpose	Research activities	Expected outcome
Phase 3. Lead Testing the program			
E5. Test the program	To understand organizational learning processes in problem solving	a) Refining the program b) Planning application of the program c) Applying the program (Observations, Interventions, field data) d) Evaluating and giving feedback to management	**O9.** Observed issues in applying the program
E6. Analyzing organizational learning in the program	**RQ4:** What activities support integrating new organizational practices in product realization?	Using the 4I framework for analyzing program data	**O10.** Answer / Recommendations for what elements should be in a program and what types of tools can support that

I refined the CII-program (Figure 23) before applying it as a test. An additional step was added to prepare stakeholders for applying the CII-program. The following steps in the program were also refined and adjusted based on learnings from applying the prototypes.

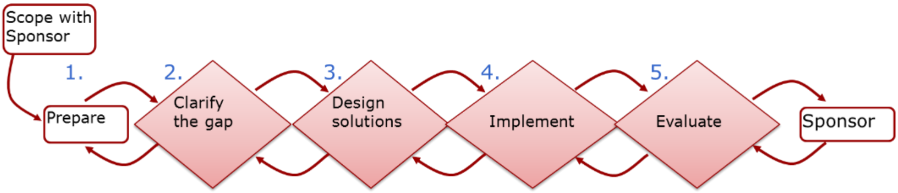


Figure 23. A refined version of the CII-program applied in tests.

1. Prepare

The purpose of scoping and preparing the CII-program was to clarify the intent of the activities and ensure that the activities made sense for those involved. The plan was to assign a sponsor to participate in scoping the CII-program together with the facilitator and the manager. During preparation, participants would form a common understanding of the current state of, for example, the production process, and seriousness of the problem. Participants would also form a common understanding of what they would want to achieve with the program, and they would clarify which factors could influence the problem and what resources were available. Expectations for the outcome of the CII-program would be stated as targets, a process objective and a learning objective. Scoping the problem was expected to ensure that participants could work rationally on the specified problem.

2. – 5. Clarify gap, Design solutions, Implement, and Evaluate

The following four steps in the CII-program aimed to enhance participants' understanding of problems related to cross functional work practices in product realization. Participants were expected to explore more optional methods and solutions, select and implement a solution as well as evaluate and share learnings with others in the organization. Within each of the four steps, the activities supported a rhythmic shift between divergent and convergent thinking in order to support proposing several options (divergent) and selecting options (convergent) based on a pre-defined set of design criteria.

Completed research activities in Phase 3. Lead Testing the program

The planned tests of the CII-program were completed as listed below in table 43.

43. Completed research activities in Phase 3. Lead Testing the program			
Activities	***Purpose***	***Research activities***	***Outcome***
Phase 3. Lead Testing the program			
E5. Case A4 Test the CII-program in the electronics factory	To understand organizational learning processes in problem solving in production	a) Refining the program b) Planning application of the program c) Applying the program (Observations, Interventions, field data) d) Evaluating and giving feedback to management	**O9. Case A4** Implemented solutions for problems in sharing knowledge between technicians Observed issues in applying the program
E5. Case A5 Test the CII-program in tool development	To understand organizational learning processes in problem solving across production and development functions	a) Refining the program b) Planning application of the program c) Applying the program (Observations, Interventions, field data) d) Evaluating and giving feedback to management	**O9. Case A5** Solutions for problems in sharing knowledge across functions Observed issues in applying the program
E5. Case B4 Test the CII-program in Engineer-to-order	To understand organizational learning processes in problem solving in a project environment	a) Refining the program b) Planning application of the program c) Applying the program (Observations, Interventions, field data) d) Evaluating and giving feedback to management	**O9. Case B5** Solutions for problems in sharing knowledge from one project to the next Observed issues in applying the program

E5. Case A4 Test the CII-program in the electronics factory

A newly appointed senior plan manager first planned to carry out the tests in relation to the MGE2/GEMS production lines. However, a newly appointed production supervisor and a local lean manager insisted on following the lean problem-solving process as customary instead of following the steps in the CII-program. The senior plan manager, central lean manager and I therefore decided to stop the test and replace it with case A4. Planning and negotiating the tests took approximately four months.

Case A4 thereafter focused on establishing a common repair process across the production lines in the electronics factory. Prior to testing the CII-program, the senior plan manager assigned eight technicians to a new analysis function and appointed a supervisor. The senior plan manager, a quality manager and a lean manager scoped the task two months before the following activities took place. Technicians, the supervisor and the local lean manager (as an observer) participated in testing the program. The group clarified problems, suggested alternative solutions and implemented the solutions concurrently as part of the program. These activities took place on two and three successive days within three weeks. After approximately three months, the participants evaluated the program test in a chronicle workshop.

O9. Case A4 Outcome of testing the CII-program in the electronics factory
As an outcome of testing the program in the electronics factory, the newly formed analysis function reorganized the layout, freeing up 41% of the allocated space. The function then designated the freed-up space to incoming and outgoing controls visualizing the function's workload. Furthermore, the technicians established a board with key performance indicators and formalized a meeting structure. There were several more suggestions to improve cross-functional collaboration within the function and with other functions, which the supervisor intended to continue pursuing.

E5. Case A5 Test the CII-program in tool development
Case A5 aimed at improving a tool development process across a composite factory and AME (Advanced Manufacturing Engineering), a newly formed function within technology. The tool development process comprised designing, testing and ramp-up in production of an injection mold tool for a coverlid to a specific pump controller (UMP3). AME initiated this specific tool development process, as new methods (molding three materials into one tool) could contribute a significant reduction of cost and transfer the production back from a supplier. However, the project team faced delays and quality problems in the development process. A production manager and a maintenance manager from the factory as well as a design manager and a lean manager from AME scoped the task two months before the following activities, which included clarifying problems, suggesting alternative solutions and planning implementation of selected solutions. A large group carried out the first activity (clarifying the problems) over two successive half days with 10 representatives from product development, the composite factory,

maintenance, AME, lean and a project manager responsible for the development process. The following activities (designing suggestions) took place two weeks later over three half days and included only four participants. Two chronicle workshops evaluated the test. In one group, managers in AME and the factory evaluated the scoping process, and in the other four groups, representatives from the remaining participants evaluated activities clarifying the problem and designing suggestions.

O9. Case A5 Outcome of testing the CII-program in tool development

AME and the factory implemented two suggestions concurrently with the test and initiated negotiations for a third suggestion. The two implemented suggestions included holding a lessons-learned meeting with stakeholders from the factory, manufacturing support and AME. Furthermore, AME and maintenance technicians formalized weekly meetings with manufacturing support at the factory to visualize the pipeline of incoming new tools. The third suggestion included formalizing a functional activity list applied by one of the participants, which implied determining roles and responsibilities, needs for competencies and activities at each step as well as negotiating use of the list across functions in AME, product development, the factory and manufacturing support. The purpose of this third suggestion was to streamline the process of designing and implementing new tools in the factory.

E5. Case B4 Test the CII-program in Engineer-to-order

Case B4 followed up on the problems identified in case B3. The management team scoped the task and formed a new group to participate in testing the program. Scoping the task comprised setting objectives and design criteria for solutions. The task was to suggest solutions to eliminate recurring deviations in projects, and the criteria for the design were that there could be no new IT-system, should include clear roles, should be fact based and easily accessed. The four participants represented production, logistics, engineering and quality functions with the quality manager as appointed leader of the group and myself as facilitator. The group met one day a week over a period of four weeks. The main activities included brainstorming solutions, creating a number of prototypes, testing the prototypes and selecting one to two solutions based on the design criteria. After three months, I evaluated the prototypes and tested CII-program in a chronicle workshop, inviting all participants from the case studies, of which seven of ten participated.

O9. Case B4 Outcome of testing the CII-program in Engineer-to-order

The group had 34 suggestions and chose to specify two prior to a presentation to management represented by the production manager. The first suggestion was to categorize deviations into five groups according to cost and implications to customers. The second suggestion aimed at adjusting project evaluation meetings so that large projects would receive a more thorough evaluation, include representatives from all functions delivering to the project and share a resume of the evaluation with the management team.

Data collection in Phase 3. Lead Testing the program

I tested the program in three case studies and collected data through intervention diaries, recordings from workshops, notes and participants' self-evaluations. Table 44 includes a short description of case studies A4, A5 and B4.

44. Case descriptions for Phase 3. Lead testing the program. One case in company A was initiated but discontinued (1 workplace observation, 6 status meetings, 4 program activities)			
	Case A4	***Case A5***	***Case B4***
Case period	**November 2016 to June 2017**		**November 2016 to June 2017**
Functions	Analysis function in the Electronics factory	-Technology development	Deviation process from assembly to Engineering
Participants	Factory manager, production supervisor, technicians, Lean managers	Technology manager, operations manager, maintenance manager, lean manager, project manager, product designer, process designer	Project manager, production team leader, quality manager, engineering designer, production preparation technician
Problem in focus	Establishing an repair process across production lines in the analysis function	Collaboration between AME technology function and the composite factory on tool design process from DP3 to DP5	Recurring deviation from one project to the next (continuing)
Situations and activities	Problem solving meetings in analysis function and meeting room	Problem solving meetings in meeting room	Problem solving meetings in meeting room
Steps in the program	-Scope and prepare -Clarify the gap -Design solutions -Implement Evaluate	-Scope and prepare -Clarify the gap -Design solutions -(Implement) Evaluate	-Scope and prepare -(Clarify the gap) -Design solutions -Implement Evaluate
Data generation activities	7 status meetings 7 program activities (incl. chronicle workshop)	1 workplace observation 1 meeting (participating) 6 status meetings 12 program activities (incl. chronicle workshop)	3 status meetings 11 program activities (incl. chronicle workshop)
Types of data	-Observational notes -Personal notes -Intervention diary Self-evaluation	-Observational notes -Personal notes -Intervention diary Self-evaluation	-Observational notes -Personal notes -Intervention diary Self-evaluation

E6. Analyzing the tests of the program

Sub-question RQ4 comprises two parts: what are the outcomes when organizational functions A. apply organizational learning processes to develop product realization processes and B. develop product realization processes as a part of daily operation. I analyzed data from the case studies in the second and third phases (A2, A3, A4, A5, B2, B3, and B4) using the 4I framework (Crossan et al. 1999). The 4I framework describes feedforward organizational learning processes as exploration and feedback organizational learning processes as exploitation. For sub-question RQ4, I analyzed data from the seven case studies using the 4I framework to study the activities in the CII-program that facilitated organizational learning processes.

E6. Analyzing organizational learning in the program in case studies A2, A3, A4, A5, B2, B3 and B4

For RQ4, the object of analysis was the activities facilitating organizational learning processes in the CII-program. I used concepts listed in table 45 from the 4I framework, coding data deductively.

45. Concepts from the 4I framework used for analyzing organizational learning processes when developing product realization

Code group	***Concepts***
Intuiting/attending	Communicate, Reflection, challenging cognitive maps
Interpreting/Experimenting	Challenge, collective action, collective thinking, communicate, inquiry, reflect, shared meaning
Integrating	collective action, collective thinking, shared meaning
Institutionalizing	collective action, collective thinking, communicate, knowledge
Organizational boundary	Individual, group, organization

O10. The outcome of analyzing organizational learning in the program in case studies A2, A3, A4, A5, B2, B3 and B4

These outcomes from the analysis and evaluations from program tests contributed suggestions for further refinements of the program.

7.6 Phase 4. Share and discuss the program

The purpose of the fourth phase of the program was to share and discuss the program with other companies. These activities include network meetings with Danish companies and supplementing tests in SMEs carried out by Force Technologies as shown in table 46.

46. Research activities in Phase 4. Share and discuss the program			
Activities	***Purpose***	***Research activities***	***Expected outcome***
Phase 4. Share and discuss the program			
Sharing with Innovation managers at DI	Verify whether preliminary observations are relevant for others than the case companies	Dissemination	Focusing relevance for others
Sharing with consultants from Force Technologies	Plan test in SMEs	Dissemination	Planned tests of the program in SMEs done by Force consultants
Sharing with Swedish companies	Verify whether preliminary observations are relevant for others than the case companies	Dissemination	Focusing relevance for others

The outcome of sharing and discussing the program with other companies in different settings contributed suggestions for further refinements of the program.

7.7 Evaluation of research quality

In the following section, I discuss the validity and reliability of the data used in this research project in order to explain how I have ensured quality research. I considered construct validity by using two typical case companies, multiple sources of evidence, sharing intervention diaries with participants and presented preliminary observations to management. I considered internal validity of the study by taking into account organizational changes and lay-offs in both companies, my introduction to the participants and by taking notes on activities not directly part of the program-activities. I checked for external validity by sharing the program with other companies and with consultants from Force Technologies. As I was participating and facilitating activities in the case studies, I considered my own errors and bias as well as participants' errors and bias to ensure reliability of data.

To ensure quality in research, I paid attention to construct validity, internal validity external validity and reliability (Voss et al. 2011; Saunders et al. 2012). Table 47 summarizes these four dimensions of quality in research, and the following elaborates on how I handled them in the project.

47. Research quality was ensured by paying attention to construct validity, internal validity, external validity and reliability (Saunders et al. 2012; Voss et al. 2011)

	Definition	***Considered in this project***
Construct validity	"… the extent to which your research measures actually measure what you intend them to asses." (Saunders et al. 2012)	- two typical case companies - using multiple sources of evidence - participants read intervention diary - preliminary observations presented to management
Internal validity	"… is established when your research demonstrates causal relationship between two variables." (Saunders et al. 2012)	- organizational changes and lay-offs - introduction to participant - activities outside the interventions - tools used in interventions change during prototyping
External validity	"… is concerned with the question: can a study's research findings be generalized to other relevant settings or groups?" (Saunders et al. 2012)	- sharing with other companies - sharing with Force consultants for further tests
Reliability	"… refers to whether your data collection techniques and analytic procedures would produce consistent findings is they were repeated on other occasion or if they were replicated by a different researcher." (Saunders et al. 2012)	- participants' errors and bias - researcher errors and bias - case study database

Construct validity

As the two companies differ in size and type of manufacturing enterprises (see the chapter on the empirical context), I found they represented typical cases for manufacturing enterprises (Saunders et al. 2012; Crabtree & Miller 1999). As described in the presentation of the two manufacturing enterprises, one company was a medium-sized company delivering Engineer-To-Order machinery while the other was a large company delivering Make-To-Stock pumps. The two typical cases served the purpose of illustrating in-depth knowledge about a particular case with no intention of being definitive (Saunders et al. 2012). Research within operations management could provide practitioners with solutions for practical problems (Voss et al. 2011).

Using various data sources and sharing intervention diaries with participants serve the purpose of triangulation to increase reliability (Saunders et al. 2012; Dubois & Gadde 2002; Creswell 2014; Voss et al. 2011). In the initial semi-structured interviews, I explored which organizational challenges respondents considered to be important in their respective department (Saunders et al. 2012). Sharing preliminary observations with managers and especially the appointed contact persons allowed contact persons to correct misunderstandings and provide supplemental nuances for interpretations. For the same reasons, participants received my intervention diary from interventions.

Internal validity

Organizational changes took place in both companies during the project. In company A, the new COO initiated his position in September 2015 following the series of workshops about a future production system. The output of the workshops was not implemented, strategic focus was slightly changed and several organizational changes followed. Consequently, my initial contact person changed positions and a new contact person was appointed. The technology director, who represented the company in the MADE work package, was on sick leave during the second half of the project. The technology department was reorganized into an expertise-oriented functional structure. Additional changes occurred in the electronics factory. The factory was moved from one location to another during the spring of 2015, while the factory was also targeted for a Lean Lighthouse project focusing on factory management. The factory had only one operations manager in the beginning of the project in 2015, as another operations manager had left for a new position. An additional operations manager started in the autumn of 2015. Then, during the summer of 2016 both operations managers left and were replaced by a promoted production supervisor. Simultaneously, a new factory manager was appointed to the electronics factory and took a more active part in the daily operations. Interventions in company A took place at the GEMS/MGE2 production line and analysis function. These two functions had the same production supervisor, which was also changed in the summer of 2016.

In company B, absent demand in one business unit and a lack of incoming new projects in other business units led the company to lay-off employees in the autumn of 2015, including one of the designers taking part in the first series of interventions. Additionally, a participating designer left for a similar job in another company. Then, only two of the original four members of the project group in the first interventions took part in evaluating the interventions. Demand was restored a few months later, which led to major growth and hiring of designers in 2016, leading to constrained resources for interventions as well as delays in the spring of 2017. A change of finance director in the summer of 2016 however did not significantly influence the project. All these organizational changes in the companies are included as events in a time-series analysis in order to study the extent to which they influenced research activities.

Another aspect of internal validity concerns information I gave to participants in connection to interviews and intervention. I minimally shared Information regarding was looking for, though I gladly took part in daily conversations at lunch tables or while sitting in the offices and inviting organizational members to approach me for further information. Similarly, I deliberately kept instructions at interventions to a minimum, with no indications of what I was looking for. However, I shared my intentions for analyzing data with contact persons in the two companies.

As the focus of research was on living practice in daily operations, product realization processes occurred and evolved in parallel with the interventions. Other activities therefore blend into the outcome of using the program, and these instances, as they came to my knowledge, were included in the time series analysis. Also included in the time-series analysis are tools and guidelines that evolved during the prototyping program development. The interventions could therefore not be compared, as they did not share preconditions.

External validity

Even though the two case companies were typical of manufacturing enterprises in Denmark, research from this project cannot necessarily be generalized to other companies in Denmark. To ensure generality, I took part in open lab meetings organized by MADE to talk to representatives from other Danish manufacturing enterprises. I also conducted a small workshop with product development and innovation managers at a network meeting organized by the Confederation of Danish Industries. These managers gave me an insight into what challenges they have experienced and how they tried to handle it. Taking a production innovation course in Sweden included visits at Swedish manufacturing enterprises, an external stay at Mälardalen University in Sweden without further visits at Swedish companies and discussions with the Swedish research team provided me with feedback on the program. Feedback from these various activities have ensured me that the program is relevant for manufacturing enterprises, at least within the Scandinavian area.

As an additional test, I shared the program with five consultants at Force Technologies who intended to use the program without my participation in other small Danish manufacturing enterprises. These test would be carried out in autumn of 2017, meaning that the results were not available for this dissertation.

Reliability

Practicing action research necessitates a researcher's sensitivity, confidentiality and caution in not harming the researched object, such as when organizational members take part in the activities (Saunders et al. 2012). I used transparent plans for research activities and frequent dialogues about next steps as prerequisites for gaining mutual trust in the project (Schein 1999). Both researcher bias and participant bias can threaten validity in action research (Paul Coughlan & Coghlan 2002; Saunders et al. 2012). Table 48 below lists my reflections concerning participant errors, participant bias, researcher error and researcher bias considered in this project.

48. Reflections on participant errors, participant bias, researcher error and researcher bias considered in this project		
	Definition	***Considered in this project***
Participant error	"Any factor which adversely alters the way in which a participant performs." (Saunders et al. 2012)	- organizational politics - stakeholder intentions - task and process reflections
Participant bias	"Any factor which induces a false response." (Saunders et al. 2012)	- loyalty (or even disloyalty) to the organization and managers - prior experience with research - participants' and organizational values
Researcher error	"Any factor that alters the researcher's interpretation." (Saunders et al. 2012)	- my personal intentions
Researcher bias	"Any factor which induces bias in the researchers' recording of responses." (Saunders et al. 2012)	- my personal experience and values

Participants in interviewees could distort challenges reported in interventions and interviews to promote their own internal agendas (Maxwell 2013). Therefore, I ensured that my sources came from different parts of the organization. Being close to and spending great amounts of time in the organizations also resulted in my favoring certain agendas. As time went on, I found myself in a limbo trying to keep the organization at a safe distance while becoming acquainted and building trust with organizational members (Coghlan & Brannick 2014). Stakeholders' intentions on behalf of the project were also a source of participant error, as participants might individually have diverse motivations for contributing to the project. As a further source of participant error, some of the participants did not distinguish the actual product realization process of focus from the course of interventions forming the program activities. I observed a few examples of this type of error in the chronicle workshops, where participants collectively reflected about tests of the program. This left me to make assumptions when analyzing data.

Participant bias could influence the project through participants showing loyalty (or even disloyalty) to the organization and individual managers idealizing or worsening their narratives (Maxwell 2013). Concerns regarding participants' bias therefore influence my considerations regarding anonymity and confidentiality about what was being discussed in and outside research activities. Even though frank statements enriched data, they also needed to be supported by other data. Many of the interventions were audio recorded for primary observations, so I could return to the statements. I chose not to use video recordings or pictures of participants in order to ensure confidentiality and anonymity of participants, allowing them to speak freely about their concerns and interpretations of the organizational challenges. However, not using video recordings excluded the opportunity for structured observations of participants' behavior (Saunders et al. 2012), which I could not conduct while facilitating the interventions.

The two companies had prior experience in participating in research projects. Company A was especially a major contributor to MADE, taking part in several work packages and another project in work package seven. However, it was my impression that they were more experienced with inductive reasoning from interviews when studying organizational issues than abductive action research implying a mutual learning process. I also noticed impatience for achieving solutions, which hampered the process of mutual inquiry into the reached topic. In addition, I noticed difficulties in ensuring acceptance for cross-functional activities in company A, which contributed to a lack of progress in developing the program. In company B, research activities were primarily proponed and prolonged by participants due to busyness.

My personal experience and values could exclude data from my attention and direct interpretations of data (Paul Coughlan & Coghlan 2002; Saunders et al. 2012; Coghlan & Brannick 2014). When making observations and writing intervention diaries, I needed to pay attention to my own bias that could potentially direct interpretations subjectively (Saunders et al. 2012). To prevent this bias, I shared intervention diaries openly with participants to ensure reliability through verification (Saunders et al. 2012). In addition, using audio recordings for the majority of interventions made it possible to go back and check what really happened. The recordings were primary observations and intervention diaries secondary observations (Saunders et al. 2012). Contextual data such as program descriptions, materials and pictures from the intervention supplement the observational data (Saunders et al. 2012). My personal reflections and experience, noted in the observation paradigm using the "left hand column" method (Argyris & Schon 1996), and a personal diary were included as experiential data (Saunders et al. 2012). As the researcher, I could herewith confront my own theories-in-use and account for bias while analyzing data, even though these notes were subjective.

Part IV Case description and program design

The purpose of Part IV is to present the empirical case studies in two manufacturing enterprises as well as the process of designing the CII-program. Two case studies clarified challenges related to cross-functional collaboration in product realization as preliminary findings that the companies could address with the CII-program. I subsequently designed and applied prototypes and tested the CII-program. I developed the CII-program to support two companies solving problems related to these cross-functional challenges in product realization.

Chapter 8 Case description of challenges in two manufacturing enterprises describes cases A1 and B1. I first describe the cross-functional challenges according to the Star-Model for each of the two cases. Introduction of new products and processes in a lean production system describe product realization processes in case A1, and recurring engineer-to-order projects describe product realization processes in case B1. I summarize the challenges across cases A1 and B1. The purpose of Chapter 8 is to clarify relevant challenges the two companies could address when applying the CII-program.

Chapter 9 Designing a continuous improvement and innovation describes the probe-and-learn development process, prototypes of the program, applications of the prototypes, the final CII-program and program tests. Firstly, I introduce the probe-and-learn development process. Secondly, I present the first set of design criteria, the prototype of the CII-program and the application of the program in cases A2 and B2. Thirdly, I present the second prototype of the CII-program and its application in cases A3 and B3. Fourthly, I present the refined design criteria, the CII-program and the test in cases A4, A5 and B4. Finally, I summarize the preliminary findings across the seven cases. The purpose of Chapter 9 is to present the completed design process of the CII-program.

8 Case description of challenges in two manufacturing enterprises

This chapter presents the challenges related to product realization in company A and company B. Case A1 has a lean production system with recurring introductions of new products and processes. Case B1 is a project-oriented production system with recurring engineer-to-order projects. I based my data collection for cases A1 and B1 on interviews, observations and field notes as described in Chapter 7. In the interviews, I ask the respondents about the company's challenges and how these challenges influenced the respondent's area of responsibility. In the data, I looked for challenges related to organizational ambidexterity in cases A1 and B1.

The following two sections present the cross-functional challenges in product realization for cases A1 and B1 according to the elements in the Star-Model (Galbraith et al. 2002). I first describe the strategy and objectives of the production system, the organizational structure, the product realization processes, incentives for developing product realization processes and resources for developing product realization processes. I then summarize the challenges across cases A1 and B1.

8.1 Case A1: the organizational design in company A

Company A is a manufacturing enterprise founded in 1944 and presently one of Denmark's few large and global manufacturers. Company A is family owned with the founder's son heading the board and the grandson as member of the executive leadership team. Company A designs and manufactures pumps and engines in their own name and for several other brands. It has approximately 18,500 employees in 56 countries (4,350 employees in Denmark) and manufacturing locations in Denmark, Hungary, China, Serbia, USA and Mexico, just to mention some of the 14 production companies. A group seven executive directors comprises: CEO & Group President; Operations; Business Development; Sales, Marketing & Service; Human Resource; Finance, IS & Legal Affairs; Communication, Public Affairs & Engagement. Research for case A1 took place in an electronics factory and with the management team of a technology center.

Strategy: production system objectives

Company A identified five “must-win battles” in their strategy plan towards 2020: funding the journey (cost conscious, transparent and decisive), supply chain (end-to-end supply chain adding value), product leadership (leading and differentiated product portfolio), service (service as commercial differentiator) as well as customer and collaboration (customer centric and collaborative culture). Company A deployed enterprise objectives to Tactical Implementation Plans (TIP) and Key Performance Indicators (KPI) for functions throughout the organization. These plans and KPIs were a focal point in the factory’s management system and were openly displayed in Obeya[3] at the factory. Figure 24 shows an example from the electronics factory.

The electronics factory had to justify their existence, as suppliers that could manufacture the parts. Consequently, they focused on efficiency and redusing costs while receiving new products they had to incorporate into the ongoing production.

[3] Obeya or Oobeya (from Japanese 大部屋 "large room" or "war room") refers to a form of project management used in Asian companies (including Toyota) and is a component of lean manufacturing and in particular the Toyota Production System. https://en.wikipedia.org/wiki/Obeya

Figure 24. An example of an Obeya with KPIs in the electronics factory in 2015.

Total quality management and lean institutionalized in shop floor excellence had influenced the production system for decades. The company considered themselves as one of the lean-forerunners in Denmark. A shop floor excellence department of approximately 25 internal lean managers supported lean at the Danish facilities before an organizational change in the autumn of 2016. Shop floor excellence operated Lighthouse projects at the factories to support management teams in developing the local management system.

Structure: Organizational structure

In the spring of 2015, operations organized its functions as below illustrated in Figure 25. A senior plant manager was responsible for the electronics factory, referring to a supply chain manager. Manufacturing support functions and supply chain management (planning) worked in a matrix with specialists allocated to specific production lines in the factories. The technology center included development functions for technology, production, product introduction, engineering and shop floor excellence.

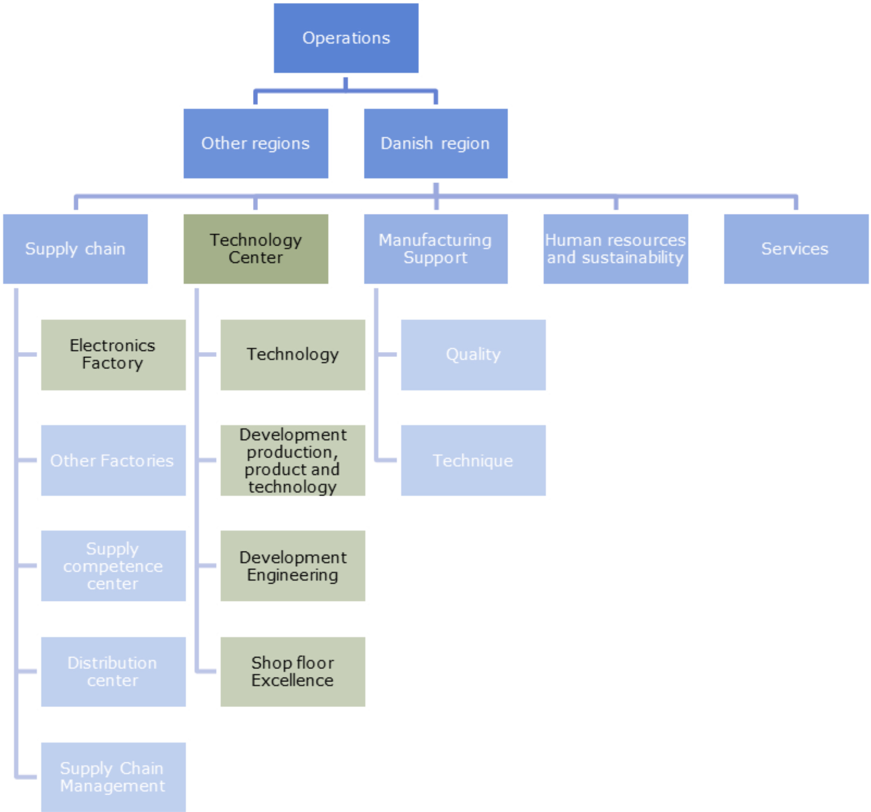


Figure 25. A simplified organizational structure in the spring of 2015, when interviews and observations for case A1 were completed. The electronics factory and management team of the technology center participated in the activities (marked with green).

Besides a senior plant manager, the electronics factory had one operation manager, a vacant operation manager position and seven production supervisors. The production supervisors were each responsible for one or two production lines. Furthermore, the electronics factory included technicians designated to the production lines. Each technician specialized in specific products and referred to production line supervisors.

The operations managers and production supervisors allocated the first part of their day to a series of daily huddles. Management meetings included e.g. status updates on staffing levels of production lines across the factory and distributing staff according to a prioritized plan. Production supervisors followed up on KPIs with their teams. A meeting for the entire factory attended daily huddles in teams, where they followed-up on KPIs and reported problems influencing daily operations. The teams on the production lines held weekly meetings with technicians from manufacturing support and planners from supply chain. The electronics factory revised the meeting structure and implemented a daily diary for production supervisors as part of the Lighthouse project. Production supervisors initiated improvements through e.g. Jishuken[4] and "challenge"[5] activities aimed at specific production lines in the factory. Employees appointed as facilitators who were partly involved in these activities. Internal lean managers representing shop floor excellence acted as coaches by supporting managers and supervisors in developing lean leadership behavior. The technology center's function was to ramp-up new products and production processes in production. The technology center comprised four developmental functions: technology, shop floor excellence, development production, product and technology and development engineering.

Several organizational changes took place during the studies for this project. The operations manager interviewed for case A1 in May of 2015, and the production supervisor participating in cases A2 and A3 left for other positions in the summer of 2016. A new Group COO for operations started in September of 2015, and one major change happened in September of 2016 when several group functions within operations were merged with functions in the Danish region's unit, as shown below in Figure 26.

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[4] A type of hands-on, learn-by-doing workshop. The term literally means "self-learning" in Japanese. (Lean Lexicon: A Graphical Glossary for Lean Thinkers 5th Ed. 2014)

[5] The activity is described in case A2.

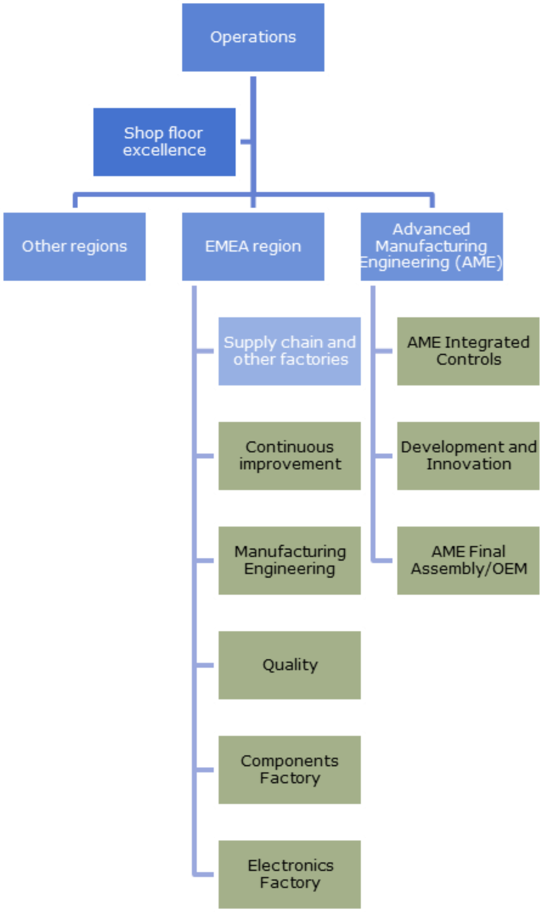

Figure 26. A simplified organizational structure in spring of 2017, when finalizing tests of the CII-program for cases A2, A3, A4 and A5. Participating functions are marked with green.

Until Autumn 2016, the internal lean managers referred to a lean director in shop floor Excellence. Afterwards, those working with the factories became part of a separate continuous improvement function and others were appointed to specific functions in direct reference to the part of the technology center that was later named Advanced Manufacturing Engineering (AME). Still, two lean managers were appointed to the electronics factory. The department designing tools for injection molding was located at the technology center in the beginning of the project but moved to the same building as the electronics factory in the summer of 2016. The department was also renamed AME in connection to an organizational change in 2016. Both the electronics factory and AME refer to operations. When I describe product realization in case A1, I refer to the organizational unit “operations” as it was in the spring of 2015 and for cases A2, A3, A4 and A5 as it was in the spring of 2017.

Processes: cross-functional product and process development

The electronics factory delivers controls for pumps. The controls include three main processes: a fully automated SMD (mounting small components on print) process, an automated mounting of larger components with few manual processes and assembly into a finished control-box. The first process takes place in a clean room separated from the last two processes. The production lines for mounting large components and assembly were designated for specific products. Testing prints was incorporated in production lines. An analysis function maintains fixtures for testers and repairs prints failing in test. The shop floor layout was optimized when the factory was moved. However, the productions lines were installed in the new building without major changes.

A seven-step life cycle from opportunity scoping to phasing out included product realization as a decision point model, as shown below in Figure 27.

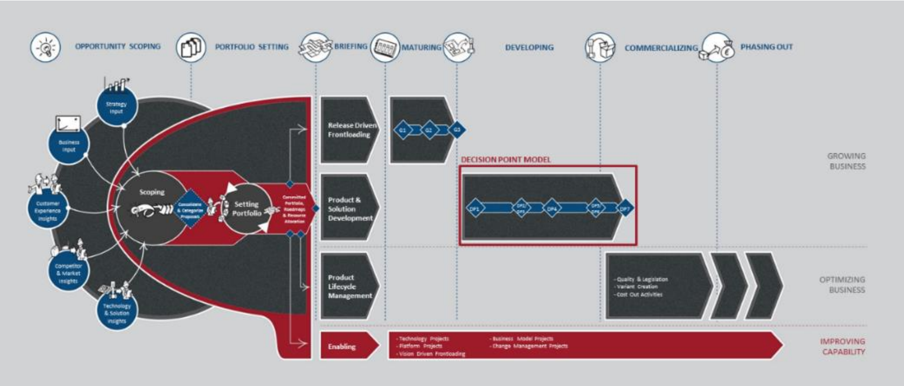

Figure 27. Product life cycle in seven steps, from opportunity scoping to phasing out.

Product and process development was organized into a decision point model defining stakeholders’ deliveries and responsibilities. The model includes a process of six phases running from project initiation, concept development, development, preparation, production start-up to sales. Figure 28 below shows the decision point model.

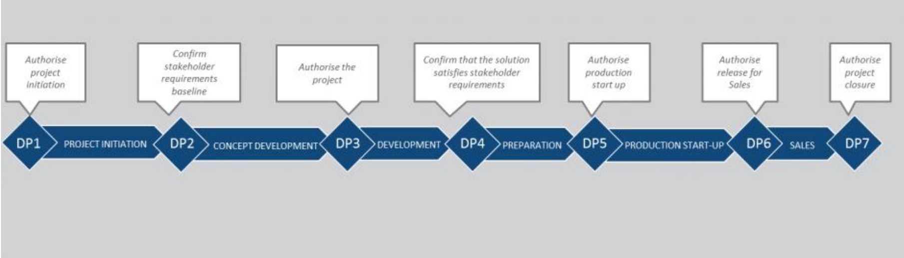

Figure 28. The decision point model in six phases from project initiation, concept development, development, preparation, production start-up to sales.

The decision point model defined meetings for giving handshakes on progressing to the next phase. Representatives from the receiving factories and manufacturing engineering functions took part in meetings and design reviews. The technology center/AME was responsible for the delivery point model and collaboration with the factories to ramp up new products and production processes.

Rewards: incentives for developing product and process development

Boards displayed KPIs throughout technology/AME and operations functions. The Lighthouse project focused on improving the factory's safety, delivery, cost and employee lean behavior. Activities in the Lighthouse project and moving the factory were included in a Tactical Implementation Plan (TIP) aligning daily operations with the overall strategy plan. However, contributing to product and process development was not part of the factory's TIP and KPIs. The electronics factory had to defend its existence while ramping up new products. On the other hand, speeding up product and process development was a focus in the TIP for technology/AME.

The electronics factory competed with external alternatives for manufacturing controls to pumps, and they occasionally used external sourcing when they lacked capacity. Consequently, they have direct benchmarking on costs. In addition, the factory continuously receives new products with uncertain forecasts. E.g., ramping up a product from 300,000 units to 2 million units within a year requires freeing up capacity and drives a focus on equipment efficiency (OPR – Operation Performance Rate). OPR and stability are also in focus when introducing new products and production processes.

People: resources for developing product and process development

The technology center played a central role in developing the factories. A few years back, senior plan managers would have resources for projects such as product and process development. At the time of the case study, senior plant managers depended on specialist functions to contribute to ramping up new products as well as to implementation of new production processes. This was also the situation for developing an improvement culture in the factories, an effort which the shop floor excellence department supported.

From the factory's point of view, the interdependencies of various projects were not sufficiently considered. The electronics factory carried out several large-change projects such as Lighthouse, new product introduction and moving the factory in the spring of 2015. Furthermore, technology appointed the electronics factory as a unit of analysis for my project as well as other projects within MADE.

Preliminary findings on challenges in case A1

The purpose of this case study was to identify challenges that I could address when applying the CII-program. As described in Chapter 7, my aim was to engage management in choosing the application area and specific task to address such challenges. I collected data about challenges in the production system for case A1 through interviews and observations, which I described in Chapter 7. I conducted some observations at a series of workshops with the technology center's management team, who intended to formulate a future production system. Therefore, I found the workshops relevant for understanding the production systems challenges.

In March 2015, the management team based their work on a future production system of strategic objectives within two years: Competitive on "cost to produce" (with lean and "design to value"); high delivery service on pumps and components; high speed in technology and product introduction, energy-optimized products and production as well as supporting sustainability profile (CSR and environment). The technology center director aimed at explaining the production system in a clear and simple way so that others could see how they could contribute. He proposed formulating explicit rules of the game such as guiding principles. Technology's management team visualized their production system as an input / output system containing following elements:

management, HR and employees; production equipment (hardware and software); business processes (immaterial flow); and layout and logistics. The management team wanted to understand each element of the production system, how the elements formed a whole, and how they interacted with each other. Management also wanted to incorporate learning, however they realized that they included the entire organization in their discussions. Therefore, it becomes more difficult than expected to align their output into a set of guiding principles. The output from the series of workshop was a comprehensive description of the elements in the production system. Shortly after the workshops, the new COO initiated his work.

At the end of the last workshop, I was asked to share my observations from their discussions. I touched on the following questions regarding the production system:

- What difficulties could there be for the production system (and sustaining it)? (Explore)
- Can we store and share knowledge in standards to secure quality and still be competent knowledge workers? (Specialization)
- How can the production system clarify competencies, roles and responsibility (Flexibility)

I exemplified their challenges and related them to theory on ambidextrous organizations as an organizational divide, such as not speaking the same language and conflicting objectives.

From a practical perspective, splitting exploration and exploitation in the organization could entail:

- Functions in the organization have different intentions, objectives and perceptions of the primary task
- Contradictions in methods from TQM/business excellence/lean
- Developing processes (technology) and leadership behavior as two different things
- Knowledge about customer needs is less emphasized in operations where the value is created

Similarly, splitting exploration and exploitation by time could involve:

- Workshops, Projects and kaizen events
- Can we utilize existing descriptions, methods from TQM/business excellence/lean and other enterprises?

- How much time do we have for the work?
- What is an appropriate level of abstraction?
- When and how to share?
- How can we visualize a complex environment in a simple way?

I also proposed alternative methods for splitting exploration and exploitation:

- Parallel experiments (reduce risk)
- Iterative and testing processes (scientific)
- Collaborative learning (ensure relevant knowledge)
- Confronting basic assumptions (utilize radical innovation)

This presentation however did not lead to any decisions besides appointing the electronics factory to the project. The following description of the challenges in company A is based on the preliminary findings in case A1.

Development functions played a central role in developing the production system and related product realization processes in case A1. The technology director was initially preoccupied with the future production system. From his point of view, it was essential for the production system to be flexible enough to adapt new technologies and optimize organizations' capabilities when introducing new technologies. Other members of the organization supported this observation and explained how difficult it was to achieve in practice. From technology's perspective, the challenge for the production system was to align the organization around product and process development. The different stakeholders in the organization were supposed to do what they were skilled at, e.g. technology was specialized in developing new technologies. Technology developed a portfolio of projects that needed integration in the factories. The specialized functions and factories comprise many agendas for developing the production system. However, technology had not shown its worth until projects were realized in practice (operations), which drew attention to the factories' role and contribution to product realization processes. Due to increasing specialization in functions, specialists introducing new products and processes in production had strayed too "far" from daily operations, which restrained transition and learning from experience. Technology recognized that equipment in production such as production lines needed to be more simple, agile and flexible.

From shop floor excellence's perspective, the challenge for the production system had two sides. First, there was a productivity dilemma, as the routinization required for efficient production flow was incompatible with the flexibility required for technology-pushed innovation. Second, there was an innovator's dilemma, as proficiency in continuous incremental improvement inhibited technology-pushed innovation and left the enterprise vulnerable to disruptive innovation originating from outside the enterprise. Shop floor excellence intended to divert focus from lean in production (resource efficiency) toward a lean enterprise with focus on flow, total productivity and adding value (effective) and use of knowledge (efficient).

On the other hand, the electronics factory (representing the production system) had to fulfill these to some extent conflicting intentions from the technology center while maintaining stable and efficient daily operations. The subsequent application of the CII-program focused on this challenge. I additionally analyze data from case study A1 in Section 10.1.

8.2 Case B1: the organizational design in company B

Company B designs and manufactures equipment for the graphic industry. The administration is located in a white building with adjacent factory facilities at three locations in the local area. There are approximately 230 employees globally and manufacturing locations in Denmark, Lithuania and the USA. Four entrepreneurs established the company in 1981 and owned the company until 2010 when a Danish equity fund took over. The equity fund expects the company to deliver stable results in both revenue and profitability. Recently in May 2017, the company announced that it was bought by another international equity fund.

The company has four business units: keyline (Key account in-line printing machines), solutions (Flexo in-line printing machines), ancillary (consumables and spare parts) and digital solution (Coating solution). Research for case B1 is based on projects in the solutions business unit. Solutions customize equipment in small series for a small number of customers and handles each order from a customer as a project. The management team consists of the CEO, CFO, engineering manager and the operations manager. The following sections primarily focus on the operations and engineering functions.

Strategy: production system objectives

Developing customized solutions to a few large customers was key to the growth of company B. Consequently, the number of orders fluctuated, which corresponded with the company's need for resources in engineering and operation functions. Achieving the capability to adapt their production to meet customers' demand for equipment was an important competitive parameter for company B. Company B aimed their sales efforts at large corporations with multiple manufacturing sites. Consequently, operations changed towards smaller series for which engineering reused designs from previous customer projects. Company B additionally rationalized its activities and tried to balance resources to meet increased expectations for a high and stable earning.

The operation function focused on earnings, delivery and quality. Operations had reduced the number of employees within the past four years. Previously, case B1 offered machining jobs with hourly pay for other customers to fill idle capacity. These jobs equaled 5% of the revenue and occupied capacity for production of parts for their own equipment, which was then occasionally outsourced to suppliers. The management team decided to categorize machined parts for the equipment into gold, silver or bronze before guiding priorities for outsourcing according to fluctuating demands. This contributed to a reduction in the number of employees and supervisors in operations and logistics and led to the closing of an apprentices department. Additionally, operations was improving shop floor layouts as an ongoing activity. These activities contributed to considerable improvements in earnings. The operations manager also focused on on-time delivery, which increased from 30-50% to close to 90%. According to the operations manager, customers demanded reliability in delivery, quality and short delivery time.

Engineering focused on earnings for each project and followed up on it regularly at standing board meetings. Staffing the projects with designers was a key topic for the engineering manager. It was difficult for project managers to calculate or estimate the need for design-hours (work time for designers) in projects. Project managers looked at previous projects when calculating costs and design-hours. According to the engineering manager, they had improved the hit rate in calculating costs and design-hours, but customers continuously demanded shorter delivery times. Miscalculations in design-hours lead to exceeding internal deadlines and budgets for projects. Exceeding deadlines consequently increased the pressure for assembly to catch up to meet the external deadline towards the customer.

Structure: Organizational structure

Customized projects linked functions together in a matrix organization. Each business unit has its own salesforce and "buys" services from the other functions. Engineering is “payed” by the hour at fixed prices regardless of whether the designer was an employee or a hired consultant. Operations manufactures key parts and assembles the equipment. Beyond operations and engineering, there were also service, product development, electronics, logistics, quality, IT and finance and a lean and documentation functions. These functions support the business units in a matrix organization, which is shown below in Figure 29.

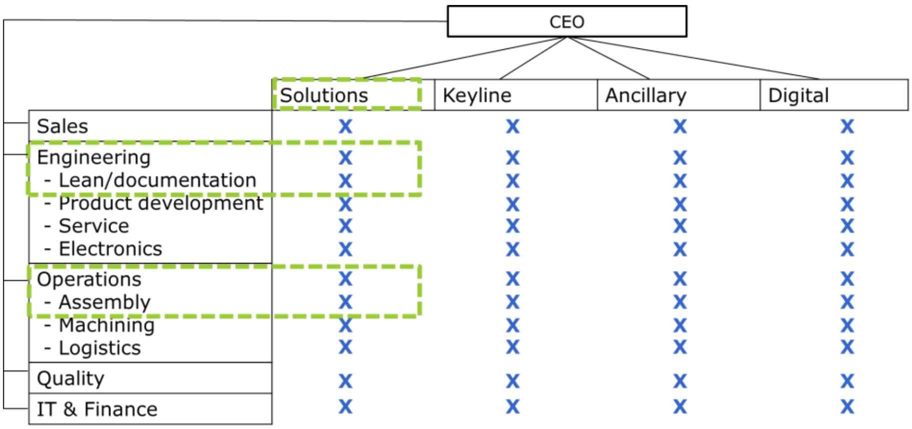

Figure 29. Project oriented matrix-organization in case B1. Participating functions are marked with green.

In operations, three production supervisors lead machining, assembly for solutions and assembly for digital. In addition, logistics manager reports to the operations manager. Assembly for solutions appoints an assembly leader for each customized project to ensure that the assembly process coordinates with logistics, engineering and machining functions. Assembly uses a flip stand for noting issues encountered while assembling. The project manager holds daily huddles by the stand and goes through listed issues with technicians and logistics. The operations and engineering managers occasionally participate.

The engineering manager assigned designers and a project manager to each project. The project groups were temporary organizations lead by a project manager, who was responsible for the project, from giving orders to comissioning the final installed equipment at the customer’s facilities. Another designated role in the project group was a design coordinator supervising the design task. The group of designers in a project was situated together while working on a project and designers therefore regularly moved around in the different offices. Implementing the matrix organization had shifted authority from the engineering manager to project managers, giving project managers closer insight into designers’ skills and performance or wellbeing. Consequently, the engineering manager spends more time planning rather than handling the softer part of management. Project managers and the engineering manager maintained a close dialogue about project statuses and distributed resources accordingly. Technical specialists were appointed for parts of product design, such as dryers and bowls.

HR leads a mid-level group meeting and the lean manager leads a monthly project manager forum. In addition, the project managers, engineering manager, operations manager and CFO participated in weekly status meetings across projects to discuss progress, problems and resources.

Processes: cross-functional engineer-to-order process at case B1

The project manager's job was to manage the project from the point when the account manager received the order to comissioning to the customer. A project manager followed a phased plan with defined roles for participants in the project. The project managers jointly developed a project model with a phase plan assisted by the lean manager. The phase plan shown below in Figure 30 was central to discussions at the project forum.

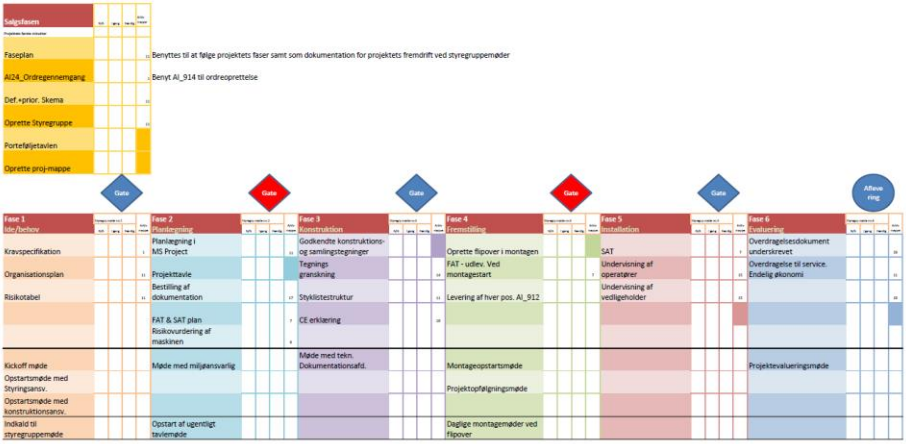

Figure 30. Project model developed by project managers (text in Danish). The project model comprises a separate sales phase (yellow top left), (following from left to right) Phase 1 Idea/need, Phase 2 Planning, Phase 3 Engineering, Phase 4 Manufacturing, Phase 5 Installation, Phase 6 Evaluation.

Project managers discussed different applications of the project model as the business units had different needs, with solution and ancillary as extremes. The project manager forum also discussed suggestions for refining the project model and other organizational initiatives. Meetings at project start-up and evaluation were included in the model. Knowledge about projects was stored as documentation for each project. Project managers held project start-up meetings with account managers. In some customer relationships, account managers occasionally involve project managers in the sales phase at early stages of projects. Some project managers were working closely together with customers on several successive projects.

Designers pushed parts through as they finished designs, disregarding which parts assembly needed first. Even though machining kept open lists of workloads, parts awaiting suppliers or other delays disturb the picture and made it difficult for designers to see whether there was an idle slot in machining. One issue related to suppliers raised by logistics was that there was no version control of blueprints from project to project. Each project reused earlier versions of documentation, however suppliers occasionally mistake it for a part they had made before and therefore did not make necessary changes e.g. in the CNC program. This reportedly also happened in machining.

Rewards: incentives for developing the engineer-to-order process

One day I walked into the designer's office and met a designer. The project he worked on was one where the key accountant had sold equipment that was impossible to design. "It's still cool to find a solution that makes it work anyway. It's probably one of the things that makes it interesting," he told me. For some designers, the projects that were most cumbersome were also the most challenging and interesting. Designers may change the design of a project when discovering additional customers' needs, generating additional sales. Operations however found the changes disturbing to their work. Furthermore, assembly was unable to distinguish whether the changes were due to upselling the project or due to corrections from releasing the design before it was finished.

In operations, assembly and testing were the last steps before shipping the equipment to customers, and assembly had to catch up due to delays in earlier processes. Due to time constraints, Assembly did not consistently register deviations that designers needed to correct in project documentation. Therefore, the same design failures could recur from one project to the next. Deviations such as missing measures on blueprints and holes in parts were considered disturbing and time consuming to assembly. Follow-ups on deviations on projects were to some extent considered acceptable, while designing engineer-to-order projects was non-routine work.

People: resources for developing the engineer-to-order process

The engineering function balanced resources by moving them between business units and by accepting freelance designers. There were adjustments made to the number of designers in November of 2015. A number of designers was first laid off due to a lack of orders. Then, just a few months later the company was again hiring designers as orders once again flowed in. Previously, there could be a long period before a designer or project manager met the same design challenges, which at the time of this study occurred at a much more rapid pace. The engineering functions' capability to deliver projects within budget was proven by its performance. Delivering more than one project to a customer gave the project manager an opportunity to build a closer relationship with customers.

For operations, employees has also said goodbye to colleagues while suppliers increasingly manufactured parts. There was also uncertainty regarding whether the strategy involves the company only assembling equipment in the future and not machining parts. In addition, since the operations manager was assigned two years ago an apprentice department was closed and the number of production supervisors reduced by half. The operations manager stressed the importance of employees understanding the change and what it means to them.

Preliminary findings on challenges in case B1

Similar to case A1, the purpose of case B1 was to identify challenges that I could address when applying the CII-program. In Chapter 7 I presented my aim to engage management in choosing the application area and specific task addressing such challenges. I collected data about challenges in the production system for case B1 through interviews and observations, which I described in Chapter 7. After completing the data collection for case B1, I presented my preliminary findings to the management team.

Initially, the CEO presented the company's challenge as how they can improve efficiency without compromising their innovativeness in their collaboration with customers. The CEO claimed reluctance to tie designers to bureaucracy that could hamper their creativity and capability to meet customers' needs. Interviews and observations for case B1 identified three main challenges presented to the management team. The four business units generated different needs in the business processes, which stressed the following questions:

- How do new business areas (web shop, service and pump) mature?
- How is a customer's affiliation to business areas determined in relation to the product / solution's life cycle?
- Expectation of stable revenue, but short order horizon.

The board's expectations of a stable turnover combined with a short sight for new orders and volatile order income challenge resource management in engineering and production:

- What are the departments' capacity and workload in operations?
- What are the capacity and workload of the individual employee or the project in engineering?
- How are tasks moved between, for example, sales and engineering?

Specialized knowledge about the customized equipment is stored as documentation in the projects and individually by engineers:

- What have we tried before and how far can we push the boundary this time (the interface between developing something new and adapting the design)?
- How do we ensure qualified labor (skilled workers, salesmen, designers) and how many (specially trained professionals) should we need to educate ourselves? What qualifications do we need?
- Knowledge about solutions is "stored" in the projects and individually with the employees. However, how is transparency about knowledge sharing created (transfer of knowledge about good solutions between projects)?

The management team then chose that I should focus on the last bullet addressing challenges about knowledge sharing between projects when applying the first prototype of the CII-program (case B2). The following description of the challenges in company B is based on the preliminary findings in case B1.

Case B1 provides four perspectives on the company's challenges. I have emphasized engineering and operations in the description of case B1. Engineering focuses on delivering customized solutions to the customers within the deadline and budget. Operations focuses on costs and simultaneously on catching up due to delays from engineering. Furthermore, cutting corners in engineering consequently affects costs in operations. The management team also represents two other perspectives of the company's challenges. The finance director links the development of the company to increased standardization and reuse of knowledge from one project to the next, while the CEO represents the sales department and the need for competencies within the salesforce.

8.3 Summary of the case description

Preliminary findings in both case A1 and case B1 showed challenges such as sharing knowledge, collaborating and coordinating between development functions (technology center or engineering) and operations (electronics factory or assembly).

Company A was organized into a combined matrix and functional structure that concentrated resources for development in specialized functions.

Collaboration between functions in case A1 was formalized in procedures such as the decision point model for product realization. The decision point model described a sequential workflow with sign-offs and reviews where representatives across functions made decisions regarding readiness to proceed to the next phase in the model. Company B was organized into a matrix structure in which resources flowed according to projects. Similar to case A1, the project model applied in case B1 included sequential sign-offs and reviews between the phases in the model. However, respondents in the interviews reported that the activities overlapped in order to complete projects within planned delivery timeframes.

Sharing knowledge in case A1 regarded the high degree of specialization in functions, where knowledge was stored in procedures or standards. Procedures guided which knowledge to share between functions, as subsequently shown in cases A2 (breakdown meetings) and A5 (functional activity list). In case B1, knowledge was contained within projects as well as within functions (engineering and operations). Management representatives selected problems related to these challenges in the following application of the CII-program.

Coordination of development activities for e.g. development of the production system was not aligned across functions in case A1. Additionally, the specialization in development functions contributed to limiting the production system's (the factory) influence on its own development. Furthermore, the production system lacked incentives for participating and contributing to development. Case B1 exemplified how incentives could be tied to projects and separated development of the production system from the projects. Alignment in the case of B1 related to projects.

In Chapter 9 I describe application of the CII-program on problems addressing these challenges and analyze the challenges in cases A1 and B1 in Chapter 10.

9 Designing a continuous improvement and innovation program

This chapter describes the CII-program that I designed to help integrate new organizational practices into product realization. The purpose is to present findings from the probe-and-learn process where I applied prototypes of the CII-program. The CII-program design relates to literature studies in Chapters 4 and 5, where I integrated the outcome into eight design criteria.

By applying prototypes of the CII-program, I created learning opportunities for solving problems in cross-functional collaboration. The purpose of the CII-program was to develop new organizational practices to solve specific problems in product realization processes related to cross-functional collaboration. The organizational members across functions were expected to collaborate in exploring these specific problems, uncovering possible solutions, implementing selected solutions and sharing their learnings with others through the CII-program's activities. The expected outcome of applying the CII-program was that the organizational members would be able to redesign their product realization process using feedback processes and learning opportunities across functions as a part of daily work. The input to the program is a specific problem in a product realization process and the outcome was expected to be new organizational practices integrated into product realization processes as well as insight into cross-functional collaboration, thus improving KPIs such as lead-time, efficiency and quality in selected product realization processes.

In the following, I first present the two prototypes of the CII-program and the refined CII-program design. Second, I describe the development process of the CII-program in four case studies (A2, A3, B2 and B3) in two manufacturing enterprises. Third, I describe the test in three case studies (A4, A5 and B4). Finally, I present the participants' evaluation of the CII-program.

9.1 The process of designing the CII-program

I designed the CII-program in a probe-and-learn process that provided me with early application feedback, thus enabling me to adapt and improve the program during the design process. The first prototype of the CII-program comprised a process model with four steps: clarify the problem, uncover possible solutions, implementation and sustain and share knowledge. The second prototype increased attention to a storyboard as boundary object and scoping the program with management. Then the final version of the CII-program additionally raised attention to knowledge creation processes in the program.

By studying practices and methods applied within lean thinking, design thinking and organizational (action) learning, I identified a set of preliminary design criteria for the first prototypes of the program (described in Chapter 5). As both companies were familiar with lean thinking though applying them to different extents, I chose to emphasize design thinking to avoid path dependency (described in Chapter 5). My concern was that if the activities in the CII-program were too familiar, they would solve problems in the way that they used to. In addition, my assumption was that they over-emphasized exploitative learning behaviors at the cost of explorative learning behavior. Furthermore, the MADE-steering committee expected a high degree of novelty in the outcome of applying the CII-program.

9.2 Designing the first prototype of the CII-program

I designed the first prototype of the CII-program based on my personal experience in problem-solving and continuous improvement while adding a few elements from design thinking such as framing and re-framing.

The first set of design criteria

I based the development of the CII-program on a set of design criteria to direct the facilitation and activities. Using design criteria is known from product development, when requirements are not quantifiable and the relative ranking of importance is unclear (Abernathy 1978). The design criteria describes my aims for a CII-program so that I can select activities and subsequently evaluate whether these activities worked as expected. More than striving for the perfect or ideal CII-program, I aim to illustrate how organizational members across functions can integrate new organizational practices into product realization processes.

The first set of design criteria was based on my practical experience as a lean manager in the lean journey project[6]. The lean journey is a guide using kaizen events as an engine for a stepwise lean transformation. My aim was to carve out the basic elements of the kaizen event and hand over the decision of the direction of the organizational development to management and the selection of tools to the group solving problems. Figure 31 illustrates my initial reflections on design criteria for a CII-program. At this stage, I did not call it "design criteria", and I instead called the "CII-program" a "guide" or "method" and later a "process model."

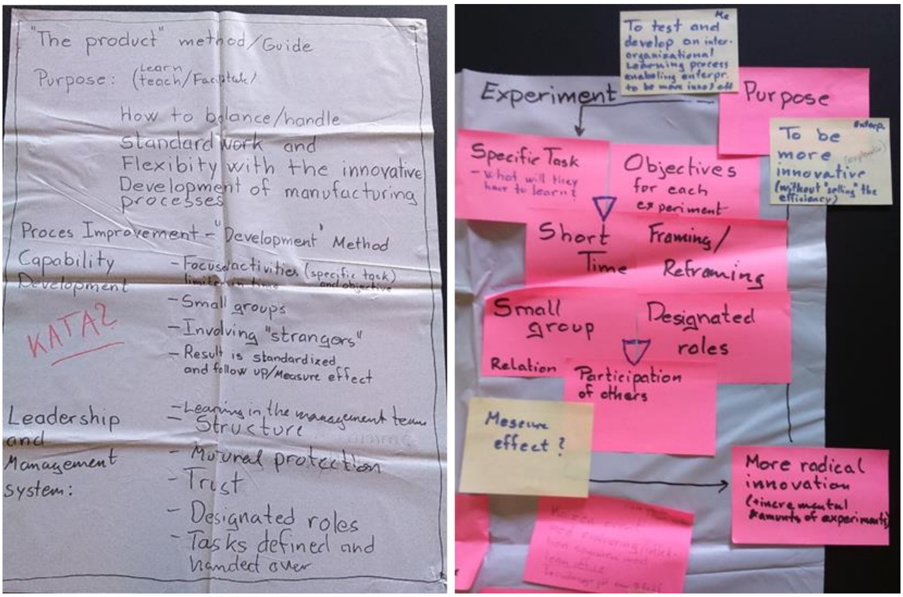

Figure 31. Flip-overs with the initial reflections on purpose and design criteria for the CII-program.

The purpose of the CII-program was to explore how to balance or handle standard work and flexibility in the innovative development of manufacturing processes. The process improvement or development method would have a capability-development approach with focused activities limited in duration with a specific task and objective. A small group of participants was assigned to the task involving "strangers" such as organizational members outside their function. The result or outcome of the activities such as countermeasures to

[6] http://di.dk/Lean/DIsguidetilleanledelse/Pages/DIsguidetilleanledelse.aspx

the problem would be contained or coded into a work standard and the effect measured for followed-up.

My intention was to pay attention to the learning process in the management team, the organizational structure, mutual protection and trust, designate roles to the participants and have management define the task before handing it over to a small group. In addition, I initially emphasized framing and re-framing as core learning activity that could break thinking habits and encourage explorative behaviors (Beckman & Barry 2007).

The first prototype of the CII-program (process model)

In the first prototype, I expected that management would select a problem based on preliminary findings from the first case studies (A2 and B2) and authorize the problem-solving activities. The plan was to set the boundaries for the problem-solving activities together with a project manager or operations manager appointed by the management team. The boundaries would include preparation, initiation of activities and evaluation. There were four steps in the process including clarifying the problem, uncover possible solutions, implementation and sustain and share knowledge. Each step includes selecting methods, exploration, testing assumptions, re-framing, concluding and presenting to others. Between each step, there should be room for reflection on the process among the participants. This reflection could include check for issues in the group (any frustrations?) and ideas or suggestions determined to fall outside the boundaries of the specific problem. The CII-program only comprised a model for the process, as illustrated below in Figure 32.

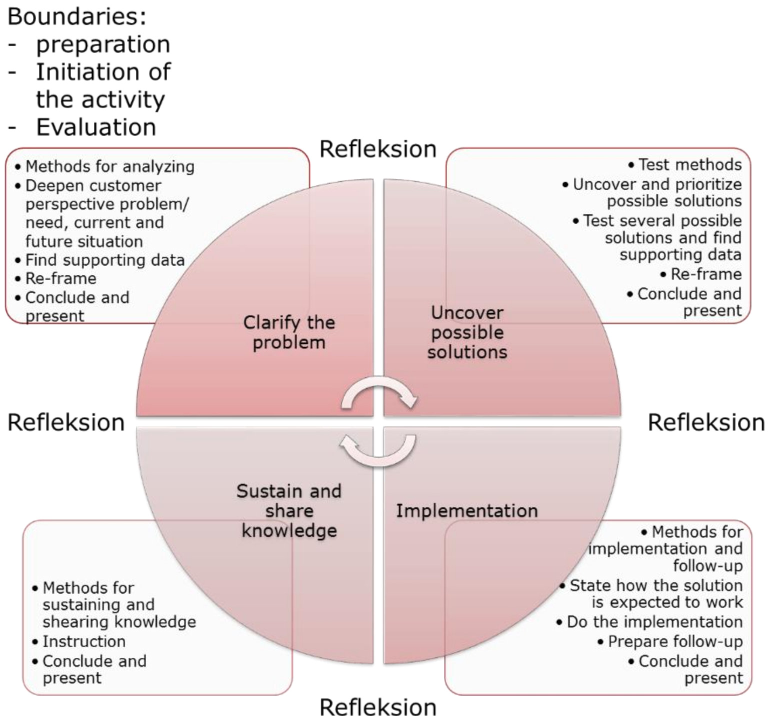

Figure 32. The first prototype of the CII-program comprised a model for the process and bullet points for managing the boundaries of the activities.

Each of the four steps would comprise a learning cycle (Dixon 1994) as well as exploration (divergent thinking), a test of assumptions (clustering) and exploitation (convergent thinking) (March 1991; Tassoul & Buijs 2007). Table 49 lists an overview of the activities and categorizes the activities according to diverging, clustering, converging and sharing behavior.

The plan was to evaluate the process together with the participants at a workshop at the end of the CII-program. The participants should then fill out a self-evaluation paradigm indicating novelty in the implemented solution, sufficiency of scoping and applicability of the process.

49. Activities in the first prototype of the CII-program

	Activity	*Purpose*	*Outcome*	*(D) diverging, (L) clustering, (C) converging (S) sharing behavior*
Boundaries				
Select problem in focus	Management representatives are introduced to the program and select a problem or customer need based on identified challenges	To understand the situation in which problem solving should take place	A shared understanding of the problem and the conditions for solving the problem	D – C
Preparation meeting	Designated leader is introduced to the program.	To prepare application of the program	A shared understanding of the problem and the conditions for solving the problem	C
Clarify the gap				
Methods for analyzing	Participants select methods for analyzing the problem / gap in customer needs.	To involve participants in planning the process	A shared understanding of the applied methods for solving the problem	D
Deepen customer perspective on problem / need, current and future situation	Participants visualize the problem / gap in customer needs that a new process or product must meet.	To establish a shared understanding of the problem / gap in customer needs	A shared understanding of the problem and the conditions for solving the problem	D
Find supporting data	Participants collects data that describe the problem / gap in customer needs.	To involve participants in analyzing the problem / gap in customer needs	Insight into the problem / gap in customer needs	C
Re-frame	Participants analyze data and visualize their findings.	To challenge the shared understanding	Insight into the problem / gap in customer needs	D

Table 49 (continued)

	Activity	*Purpose*	*Outcome*	*(D) diverging, (L) clustering, (C) converging (S) sharing behavior*
Conclude and present	Then participants visualize their shared understanding of the problem / gap in customer needs on a board.	To challenge their shared understanding of the problem / gap in customer needs with relevant stakeholders not participating.	Insight into the problem / gap in customer needs	C – S
Uncover possible solutions				
Test methods	Participants select methods for testing suggested solutions.	To involve participants in planning the process	A shared understanding of the applied methods for testing suggested solutions	D
Uncover and prioritize possible solutions	Participants brainstorm and prioritize suggested solutions to the problem / gap in customer needs.	To generate and prioritize suggested solutions to the problem / gap in customer needs.	A shared understanding of the opportunities for solving the problem	D – L
Test several possible solutions and find supporting data	Participants test suggested solutions to the problem / gap in customer needs	To involve participants in testing suggested solutions.	Insight into how the suggested solutions might work in practice.	L – C
Re-frame	Participants evaluate tests and visualize their findings.	To challenge suggested solutions	Insight into how the suggested solutions might work in practice.	D
Conclude and present	Then participants select solutions to the problem / gap in customer needs and visualize the solutions on a board.	To challenge their shared understanding of the problem / gap in customer needs with relevant stakeholders not participating.	Insight into how the suggested solutions might work in practice.	C – S

Table 49 (continued)				
	Activity	***Purpose***	***Outcome***	***(D) diverging, (L) clustering, (C) converging (S) sharing behavior***
Implementation				
Methods for implementation and follow-up	Participants selects methods for implementing selected solutions.	To involve participants in planning the process	A shared understanding of the applied methods for implementing suggested solutions	D
State how the solution is expected to work	Participants specify and describe selected solutions	To support the implementation process	Structures that ensure integration in work practices	C
Do the implementation	Participants plan and coordinate the implementation of selected solutions.	To engage participants in the implementation	Integration into work practices	C
Prepare follow-up	Participants select metrics that indicates whether the solution work as expected.	To support the implementation process	Structures that ensure integration in work practices	C
Sustain and share knowledge				
Methods for sustaining and sharing knowledge	Participants select methods for sustaining and sharing knowledge.	To involve participants in planning the process	A shared understanding of the applied methods for sharing knowledge	D – L – C
Instruction	Participants instruct relevant stakeholders in using the implemented solution.	To support institutionalization of the implemented solution.	structures that ensure integration in work practices	S
Conclude and present	Participants visualize planned instruction.	To share gained insights with relevant stakeholders not participating.	Insight into the integrated work practice.	S

Table 49 (continued)				
	Activity	***Purpose***	***Outcome***	***(D) diverging, (L) clustering, (C) converging (S) sharing behavior***
Boundaries				
Evaluate	Participants evaluate the process and implemented solutions together with relevant stakeholders that did not participate.	To gain shared insights about process and solution with relevant stakeholders not participating.	Insight into the integrated work practice.	C – S
Report back to managemen t team	Designated leader shares gained insights with management representatives	To share gained insights with management representatives.	Insight into the integrated work practice.	S

Applying the first prototype of the CII-program for a large manufacturer in case A2

Interventions contributing to developing the CII-program for a large manufacturing enterprise focused on learning from improvements on the shop floor and from cross-functional product realization processes. Challenges in product realization processes were identified in case A1 and described in Chapter 8.

In case A2, I focused on the MGE2-GEMS production line in the electronics factory. Despite mutual attempts, I had not gained access to apply the program. Instead, I continued observations of a “challenge” and breakdown meeting in connection to the MGE2-GEMS production line. My aim was to clarify existing cross-functional learning opportunities. The product is an electronic control unit for 4 - 5 product categories. The first part of the production line (MGE2) receive prints from SMD and mounts large components automatically and manually on the print. Operators then place prints in black cassettes. The second part of the production line (GEMS) assemble prints, places transformers in a box and tests the final unit. The units are then shipped for assembly in pumps in Hungary.

In a "challenge," a lean manager, a facilitator on the production line and a production supervisor tested the production line for 24 hours. According to the production supervisor, the purpose of the test was to show whether the line was properly staffed (or people leave for some reason) and the equipment worked. According to the lean manager, the purpose was to achieve as high an OPR as possible. The target for the production line the following year was 81% in OPR for MGE2 (print production) and 91% in OPR for GEMS (final assembly of control units) in order to meet expected demand. Management's intention was to increase capacity through improved OPR instead of opening an additional third shift. MGE2/GEMS was at the time running around 70% in OPR while targeting 75%. The production line was running a different product than planned due to problems in the beginning of the week. The lean manager instructed a facilitator (an appointed role for an operator) in calculating OPR and noting disturbances causing OPR to be lower than expected during the "challenge" (as shown below in Figure 33). These notes were not used as input to continuous improvement.

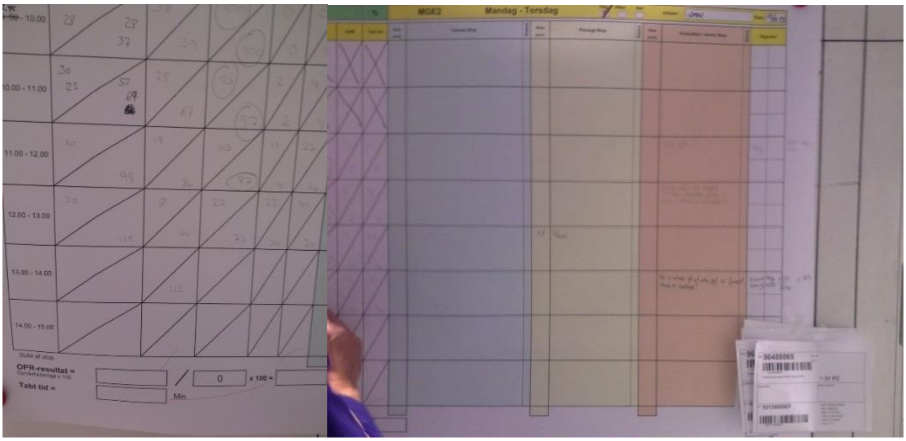

Figure 33. Calculating hourly OPR and noting disturbances.

I observed four breakdown meetings related to the MGE2/GEMS production line. The first two meetings related to the same breakdowns on MGE2: one around morning and one in the afternoon. The purpose of the meeting was to find and correct a specific failure in the soldering process. The production supervisor led the meeting and several people across functions participated (facilitator on the line, experienced operator, local technician, specialist in soldering, maintenance manager, planner and lean specialist). They used a whiteboard for the meeting, as shown below in Figure 34.

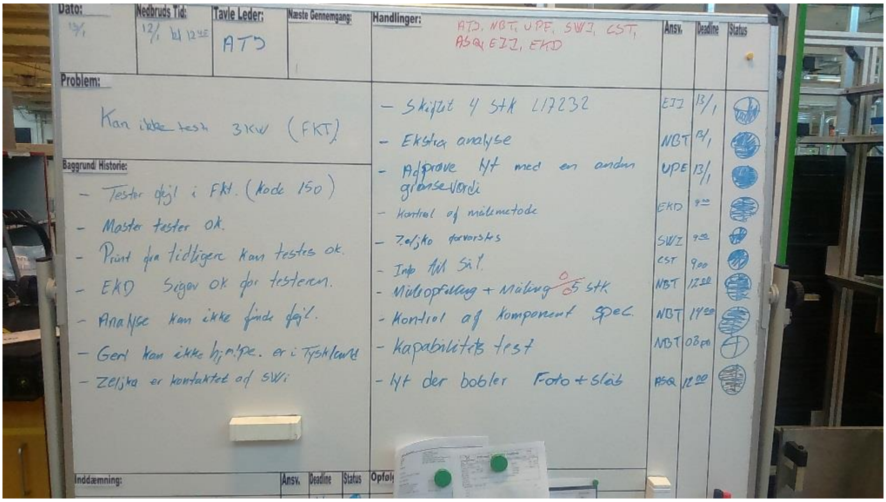

Figure 34. Whiteboard used in connection with breakdown meetings.

Brief meetings formed the basis for action status updates and deciding the next step. The cross-functional participation clarified aspects of the problem as well as consequences for the production plan. The other two breakdown meetings I observed followed the same method. According to the production supervisor, there was no connection between the issues in the breakdown meetings and the issues in the regular meetings between the team and the maintenance technicians. Table 50 summarize purpose, outcome and learnings from case A2.

50. Purpose, outcome and learnings from case A2				
Case A2	**Purpose**	**Expected outcome**	**Outcome**	**Learnings**
Challenge (Dec. 2015)	To test the equipment's capacity and train designated employees	Insight into the equipment's capacity.	Insight into situations that reduce the equipment's capacity. Knowledge about calculating OPR	The activity generated insights about problems reducing the equipment's capacity, but these insights were not utilized in other problem solving activities.
Breakdown (Jan. 2016 Mar. 2016)	To get the production line up and running again	Insight into a specific problem on the production line.	Insight into and shared understanding of the problem causing stops on the production line.	The activity generated insights about problems and their causes, but these insights were not utilized in problem solving activities for preventing similar situations.

Applying the first prototype of the CII-program for a medium-sized manufacturer in case B2

Developing the CII-program for a medium-sized manufacturer focused on learning from cross-functional engineer-to-order processes. I applied the first prototype on knowledge sharing problems identified in case B1, as described in Chapter 8.2. Table 51 shows the completed activities in case B2.

51. Completed activities in applying the first prototype of the CII-program in case B2		
	Case B2	***Period***
Boundaries		Sep. 2015
Select problem in focus	X	
Preparation meeting	X	
Clarify the gap		Sep. – Oct. 2015
Methods for analyzing	0	
Deepen customer perspective problem / need, current and future situation	X	
Find supporting data	0	
Re-frame	(X)	
Conclude and present	X	
Uncover possible solutions		Nov. 2015
Test methods	0	
Uncover and prioritize possible solutions	X	
Test several possible solutions and find supporting data	(X)	
Re-frame	0	
Conclude and present	X	
Implementation		
Methods for implementation and follow-up	0	
State how the solution is expected to work	0	
Do the implementation	0	
Prepare follow-up	0	
Conclude and present	0	
Sustain and share knowledge		
Methods for sustaining and sharing knowledge	0	
Instruction	0	
Conclude and present	0	
Boundaries		Jan. 2016
Evaluate	X	
Report back to management team	X	

I applied the first prototype of the CII-program in case B2. I observed and guided interventions developing the engineer-to-order process in a project group working on recurrent projects for a specific customer. Interventions included a project team of four designers. The customer had several plants around the world and the project team was working on the eighth and ninth pieces of equipment in a row. Each piece of equipment was customized for a specific factory. According to the project manager, 80% of the construction work was “copy pasted” from one project to the next. Previous projects had exceeded budgeted costs. Therefore, the project manager’s purpose for the interventions was to improve knowledge sharing within the project group to allow them to work more efficiently and use less time for the design work. I prepared the project manager for the interventions based on a visualization of the process (as shown below in Figure 35) and discussed the plan, activities, hypotheses, expected result and methods for measuring the outcome.

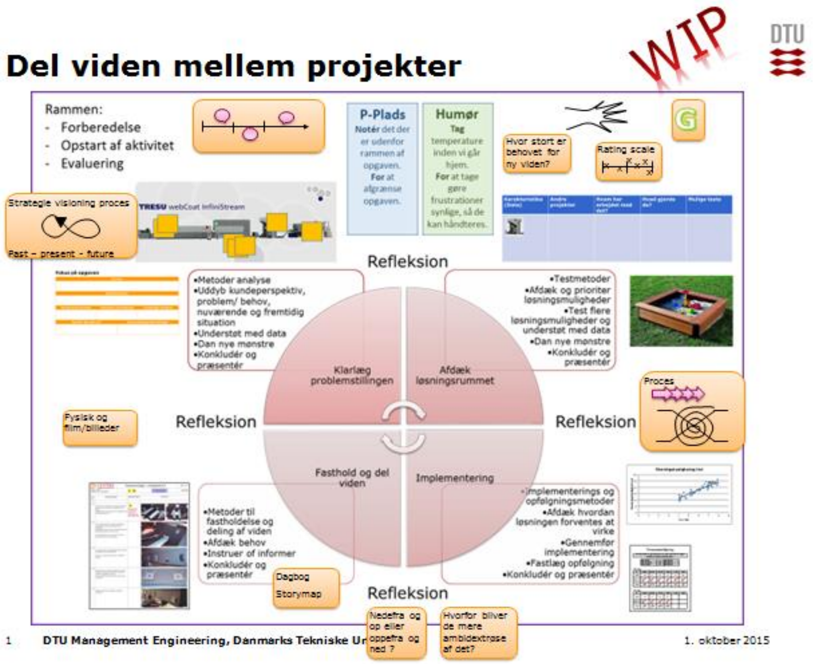

Figure 35. Visualizing the intervention process (in Danish)

The interventions resulted in a board for sharing knowledge on the current project. Although the project group was pleased with their work, they were not especially explorative regarding testing problems with facts or considering various solutions. This meant that information on the board was scarce, as shown below in Figure 36.

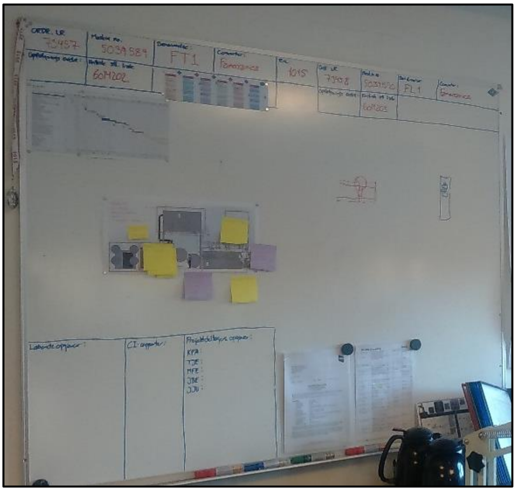

Figure 36: The board project members created to share knowledge about equipment design.

In order to avoid restricting the project members' creativity, the project group was not provided with a clear framework for a board to follow. The project group evaluated the interventions at a one-hour workshop summing up the interventions and handing over ideas for further improvements to the lean manager. In addition, the project manager for the next series of interventions participated in the evaluation workshop. The project manager and a member of the project group created a self-assessment of the process. At the time of evaluation, two of the four members of the project group had left the company. The project manager presented findings at a regular meeting for other project managers. A one-hour standing meeting provided the management team with a report on findings. Findings from case B2 provided the management team with information scoping case B3. Table 52 summarize purpose, outcome and learnings from case B2.

52. Purpose, outcome and learnings from case B2				
	Purpose	***Expected outcome***	***Outcome***	***Learnings***
Case B2	To improve knowledge sharing between projects in a project group	Structures for integrating solutions visualizing knowledge	A board visualizing knowledge in the project was integrated into work practice	Time constraints make designers cut corners and leave limited time for improving their own work practices.

9.3 Designing the second prototype of the CII-program

Learnings from further observations in case A2 and the application of the first prototype in case B2 lead to further emphasis on negotiating the boundaries of the program activities with management representatives. Furthermore, I enhanced application of a storyboard to display the process to the participants.

The second prototype of the CII-program

The second prototype of the program included the same model for the process as the first prototype, while adding a storyboard visualizing the problem-solving process for the participants as well as other stakeholders. The storyboard is illustrated in Figure 37 below.

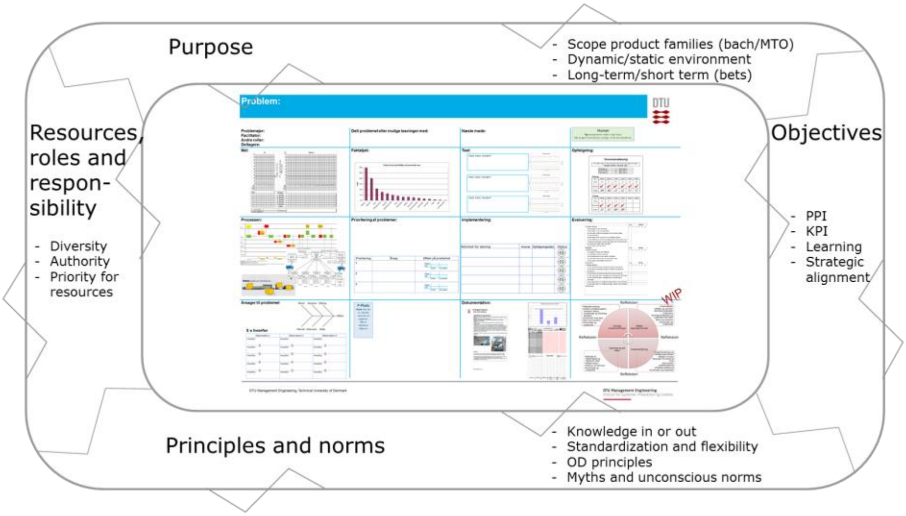

Figure 37. A storyboard visualizing the problem-solving process in the second prototype of the program. The broken frame around the storyboard illustrates the importance of scoping the process.

My aim in this application of the second prototype was to advance the test of assumptions, especially those which participants had about their colleagues in other departments. This time, I intended to progress through the four quadrants in the process in order to reach the last two quadrants: implementation and sustain and share knowledge. Furthermore, I stressed the importance of scoping the problem-solving activities with management before initiating the activities as well as reporting outcomes to management afterwards. I illustrated the scoping with a broken frame around the storyboard, as it could be necessary to renegotiate the conditions for solving the problems. In addition, the scoping specified management's role in relation to redesigning product realization processes.

Applying the second prototype of the CII-program for a large manufacturer in case A3

The following case A3 also occurred at the electronics factory, and the prototype of the program was not applied. However, this time I had the opportunity to take part in a problem-solving activity in which the participants applied the company's usual methods. As part of the production supervisor's planned activities (TIP), the task was to improve the exchange of failing print and fixtures for the testers between the production line (MGE2/GEMS) and the analysis function in order to raise the yield. Two facilitators from the production line and a technician from the analysis function formed the core of the group. A lean manager and the production supervisor partly participated. Table 53 list completed activities in case A3.

53. Completed activities in the problem-solving process framed according to activities in the prototype of the CII-program in case A3.

	Case A3	*Period*
Boundaries		
Select problem in focus	0	
Preparation meeting	0	
Clarify the gap		Mar. 2016
Methods for analyzing	0	
Deepen customer perspective problem / need, current and future situation	(X)	
Find supporting data	0	
Re-frame	(X)	
Conclude and present	0	
Uncover possible solutions		Apr. 2016
Test methods	0	
Uncover and prioritize possible solutions	X	
Test several possible solutions and find supporting data	(X)	
Re-frame	0	
Conclude and present	0	
Implementation		May 2016
Methods for implementation and follow-up	0	
State how the solution is expected to work	(X)	
Do the implementation	X	
Prepare follow-up	0	
Conclude and present	0	
Sustain and share knowledge		
Methods for sustaining and sharing knowledge	0	
Instruction	0	
Conclude and present	0	
Boundaries		Jun. 2016
Evaluate	X	
Report back to management team	0	

In the interactive process between the production line and the analysis function, operators place prints failing tests on the production line on one side of a rack. A technician makes regular rounds and picks up failing prints for analysis and repair. Corrected prints are then placed on the other side of the rack (Figure 38 left). Technicians also service fixtures for the tester to make sure they are ready for use (Figure 38 right).

Figure 38. Rack for incoming and outgoing failing prints (left) and racks for fixtures to the tester (right).

The group of operators and technicians created visual solutions for easing the exchange. Meetings were first held in a meeting room and then moved to the shop floor and used a whiteboard to track problem-solving activities (as shown below in Figure 39).

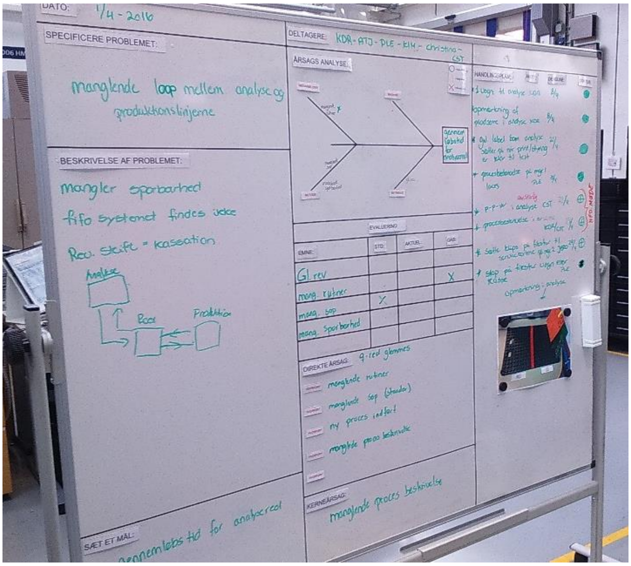

Figure 39. Whiteboard for problem-solving flow between production line and analysis.

Even though all participants found that the countermeasures had improved the flow, they were not able to show a significant effect in terms of yield. When evaluating case A3, the participants filled out a self-evaluation. Table 54 shows the purpose, outcome and learnings from case A3.

54. Purpose, outcome and learnings from case A3

	Purpose	***Expected outcome***	***Outcome***	***Learnings***
Case A3	To improve the exchange of failing prints and fixtures for the testers between the production line (MGE2/GEMS)	Structures for integrating solutions to the identified problems	Insight into the problem on the board and structures for integrating coordination between the two functions into work practice	Participants in the case focused on making a task list and completing tasks more than understanding what caused the problems.

Applying the second prototype of the CII-program for a medium-sized manufacturer in case B3

The second prototype of the program was applied in case B3. I observed and facilitated interventions developing the engineer-to-order process within a major project for a customer. The project manager aimed at reducing recurring deviations in equipment design. The interventions involved a project manager and employees from assembly. Deviations were failures that designers had to correct in the documentation of the equipment. Preparations for the interventions were similar to the previous case, though an additional resume of the preparation meeting was delivered. The activities are listed below in table 55.

55. Completed activities in applying the second prototype of the CII-program in case B3

	Case B3	*Period*
Boundaries		Mar. – Apr. 2016
Select problem in focus	X	
Preparation meeting	X	
Clarify the gap		May – Jun. 2016
Methods for analyzing	X	
Deepen customer perspective problem / need, current and future situation	X	
Find supporting data	X	
Re-frame	X	
Conclude and present	X	
Uncover possible solutions		
Test methods	0	
Uncover and prioritize possible solutions	0	
Test several possible solutions and find supporting data	0	
Re-frame	0	
Conclude and present	0	
Implementation		
Methods for implementation and follow-up	0	
State how the solution is expected to work	0	
Do the implementation	0	
Prepare follow-up	0	
Conclude and present	0	
Sustain and share knowledge		
Methods for sustaining and sharing knowledge	0	
Instruction	0	
Conclude and present	0	
Boundaries		Sep. 2016
Evaluate	X	
Report back to management team	X	

This time a large A0 sheet (Figure 40) functioned as a storyboard to direct the intervention process and list problem-solving findings. Each of the fields of the A0 (shown in Figure 32) sheet represent a step in a process to help participants clarify the gap, uncover possible solutions, implement as well as sustain and share knowledge.

Figure 40: A0 sheet functioning as a boundary object for the intervention process.

Participants highlighted two tracks of main issues in preventing deviations to reoccur in subsequent projects. First, assembly should actually register all deviations rather than just correct the failures they find. It became obvious that not all technicians find it worth the trouble to file a registration in the IT-system. In their experience, designers do not correct the failures anyway, which was the second issue. Both issues were tested in a reality check which showed that in the actual project, assembly did register the expected amount of deviations and designers did take action on them. However, when trying to determine how many of the deviations reoccurred in the following project a few months later, it was found that another assembly leader had not registered deviations in the beginning of the project. Therefore, comparisons of the deviations in the two projects were impossible. When reporting to the management team, divergence of role and responsibilities was raised as an issue. Furthermore, overlapping projects caused delays in corrections when blueprints for a project were copied before the first project was finished in assembly. The management team was also confronted with a third issue about the importance of apparently insignificant deviations. Examining deviations on a project revealed that 42% of the deviations were related to holes (e.g. placed wrong, missing, wrong diameter, missing thread). Table 56 summarize purpose outcome and learning from case B3.

56. Purpose, outcome and learnings from case B3

	Purpose	*Expected outcome*	*Outcome*	*Learnings*
Case B3	To prevent deviations from recurring in successive projects	Structures for integrating solutions that visualize knowledge	Insight into and shared understanding of the problem	The problem highlighted issues about ambiguous priorities that management representatives needed to be involved in.

9.4 Designing the final version of the CII-program: Effect and data collection

In this section, I describe how the CII-program was tested and what resulted from the tests. My aim was to evaluate the extent to which the CII-program meets the design criteria.

Refine the design criteria

I developed the final set of design criteria after using prototypes and before proposing a final CII-program to the two case companies. In this way, I based the final design criteria on participants as well as my own practical experience from applying the prototypes. Furthermore, I studied literature on organizational learning and knowledge management processes to refine the program.

There were eight design criteria, where criteria 1 to 4 concerned scoping the program and setting the contextual stage for the program (what, who, why, and when). Criteria 1 proposed a task focused design and criteria 2 specified a cross-functional design. Criteria 3 concerned authorization issues in a multi-level design and criteria 4 proposed integration into daily operations. The following criteria 5 to 8 concerned the actual process within the program, as criteria 5 proposed encouraging divergent and convergent thinking for ambidextrous behavior. Criteria 6 proposed an experimental design that encourages testing assumptions. Criteria 7 proposed a self-managing design that limits complexity for the participants. Finally, criteria 8 proposed awareness of organizational learning and knowledge processes. Table 57 list the eight criteria.

57. An overview of the eight design criteria directing development of the final CII-program

Criteria	***What***	***Purpose***	***How***
Criteria 1	Focusing on a specific task such as a problem to solve or a customer need to fulfil.	To make the subject specific, transparent and manageable for the participants.	Management representatives select and scope a task as an identified problem or need in a specific business process.
Criteria 2	Assigned a small cross-functional group of people	To bring in different perspectives and challenge shared insights.	Management representatives assigned organizational members to the task.
Criteria 3	Involve employees and managers on multiple organizational levels	To authorized the group to make small step experiments and ensure transparency.	Present insights and ideas with others not participating in the program.
Criteria 4	Integrate program activities in daily work	To encourage internalization of learnings and for the researcher to study problems in their natural context.	By including activities at places where the specific work practices take place.
Criteria 5	Encourage divergent and convergent thinking	To support explorative and exploitative learning behavior.	By combining problem solving activities in lean thinking and design thinking
Criteria 6	Confronts participants through experimentation	To gain insights about problems, possible solutions and implications in implementation and to secure validity as well as initiate learning	Visualize and challenge their shared understandings of problems, causes and contexts.
Criteria 7	Self-managed by organizational members after introduction	To gain self-renewing capacity and integrate the program into daily work practices.	By simplifying program activities.

Table 57 (continued)			
Criteria 8	Based on theory of organizational learning processes and knowledge processes.	To integrate insights into new work practices.	By stimulating learning from experimentation and experience.

Refine the program

Design thinking (Brown 2015; Brown 2008) and the 4I framework for organizational learning processes (Crossan et al. 1999) form the theoretical basis for activities in the refined CII-program. Figure 41 shows the relationship between the CII-program and the theory.

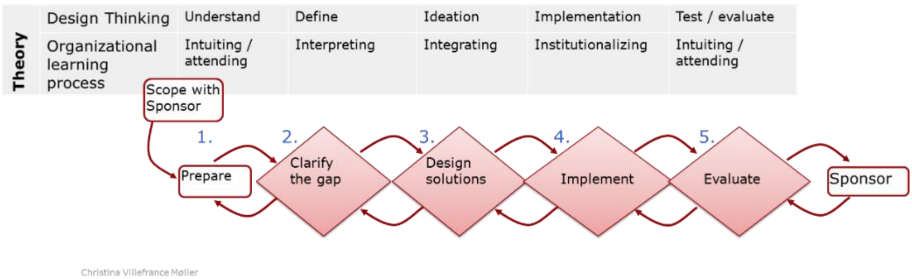

Figure 41. The CII-program related to design thinking and organizational learning processes in the 4I framework (Crossan et al. 1999).

The CII-program comprises five steps:

1) Prepare
2) Clarify the gap
3) Design Solutions
4) Implement
5) Evaluate

The first preparation step comprises scoping the application of the CII-program together with management. Managers representing different functions in the product realization process discuss cross-functional challenges and select a specific problem that can serve as a target for applying the CII-program. In addition, managers set targets related to the overall company strategy and customers' needs, discuss relevant stakeholders, highlight what is in or out of scope and appoint a cross-functional team to solve the specified problem as part of the CII-program. The purpose is to ensure management's commitment and authorization for applying the CII-program. The outcome is a scoping storyboard that provides the appointed participants with a direction for their activities in the CII-program.

The CII-program operates with three formal roles:

1) The sponsor
   a) The sponsor is a member of the management team partly or entirely responsible for product realization.
   b) The sponsor's task is to scope the task with the CII-program's focus and authorize a manager and team to work on the task.
2) The facilitator
   a) The facilitator may be a lean manager or project manager familiar with product realization processes.
   b) The facilitator's role is to facilitate activities.
3) The manager
   a) The manager may be a project manager or a production manager.
   b) The manager is responsible for the specific task within product realization processes.
   c) The manager is authorized by the sponsor to make the necessary decisions and focus on the participants' collaboration.

Managers taking part in the preparation are considered sponsors, and they do not take part in the following activities. The facilitator is the one who facilitates the activities in the CII-program, including the preparation step. The manager is authorized to lead the CII-program application and the facilitator plans the following steps in the CII-program.

The second step in the CII-program comprises various activities that serve the purpose of clarifying root causes to the selected problem that challenges cross-functional collaboration in a specific product realization process. The purpose is to provide the participants with insight into the specific problem as well as into product realization work processes across functions, their interrelationships and shared knowledge. The outcome comprises identified, categorized and selected root causes that are supported by statements tested with facts.

The third step for solution design comprises different activities in which participants create and trial several solutions for the previously identified root causes. The purpose is to generate mutual optional solutions and compare them with a set of design criteria. At least two solutions will be selected and presented to relevant stakeholders and decision-makers. Subsequently, participants will implement selected solutions and evaluate the process in chronicle workshops.

I chose the chronicle workshops as a method for evaluating the process of the CII-program together with the participants. The chronicle workshop is a method where the participants share their experience in a narrative form (Grex & Ipsen 2010; Poulsen et al. 2015).

Figure 42. The wall of yellow, orange and pink notes representing three rounds of questions in a chronical workshop. The green notes were suggestions for improving the program.

The dialogue between participants in a chronicle workshops was expected to contribute further insights in the process in the CII-program. As such, the chronicle workshop serves as an alternative to group interviews. Furthermore, using three rounds of open questions can facilitate collective reflection on specific challenges in making organizational changes. The chronicle workshops were originally used for making sense of organizational events over longer periods of 10 to 15 years (Grex & Ipsen 2010). However, the method has proven beneficial in other research representing periods of a few months (Grex & Ipsen 2010; Poulsen et al. 2015). Figure 42 show an example of the outcome of a chronicle workshop in one of the cases. Activities in the program is listed in table 58.

58. Activities in the refined CII-program				
	Activity	***Purpose***	***Outcome***	***(D) diverging, (L) clustering, (C) converging (S) sharing behavior***
Scoping				
Visualize the context map	Participants from production and development functions draw a common picture of the situation to which the idea's development should relate. The background for initiating the activities is put in perspective of external and internal factors, customer needs, uncertainties and the company's strategy.	To understand the situation in which problem-solving should take place	A shared understandin g of the problem and the conditions for solving the problem	D
Draw the problem	Participants draw the problem / gap that a new process or product must meet. Participants e.g. draw a process, a timeline or a product, and mark problems on the drawing. The group then determines criteria to meet for a final solution. Then, objectives for the outcome are set in terms of results (KPI), the process and the learning for the two functions production and development.	To understand the situation in which idea generation should take place.	Insight into the problem / gap in customer needs	L
Combine in a storyboard	Then participants collect the visualized context and problem in one drawing and add a plan for the forthcoming activities. The plan can e.g. contain available resources, participants and decision-making competence.	To prepare dissemination to employees and relevant stakeholders not participating	Insight into the problem / gap in customer needs	C

Table 58 (continued)				
	Activity	***Purpose***	***Outcome***	***(D) diverging, (L) clustering, (C) converging (S) sharing behavior***
Present the storyboard	Employees from the two functions receive a short (collective) presentation of the scope and plan for the forthcoming activities.	To offer an opportunity for internalization.	Insight into and shared understanding of the problem / gap in customer needs	S
Clarify the gap				
Design reviews of a process	Development and production employees contribute with input to innovation/ideas that need to be considered early in the development process. Solutions desired to be evaluated should be prepared in a visual manner using blueprints or physical models	To understand and ideate for future process or product development.	A shared understanding of the problem and insight into work practices across functions	D
Job swopping/ observation	Employees from development and production change jobs and gain insight into each other's work. Tacit embodied knowledge is explicated and shared across functions	To understand and ideate for future process or product development.	A shared understanding of the problem and insight into work practices across functions	D

Table 58 (continued)

	Activity	*Purpose*	*Outcome*	*(D) diverging, (L) clustering, (C) converging (S) sharing behavior*
Needs and contributions	Employees from development and production achieve a common recognition of activities, needs, and contributions in the development process, a concrete process or product across production and development. Together, participants form a picture of how the development process looks. Participants examine the coherence of needs or problems and substantiate the understanding with facts, data or tests. Based on the company's development model or a number of development process steps, a matrix is made where columns are process steps and three rows are requirements, contributions and new contributions respectively.	To generate ideas for future contributions from production to complete the activities in question in the development process.	A shared understanding of the problem and insight into work practices across functions	D

Table 58 (continued)

	Activity	*Purpose*	*Outcome*	*(D) diverging, (L) clustering, (C) converging (S) sharing behavior*
Communication landscape	Achieve clarification of information flow and need between production and development. A group of employees from production and development together build a picture of how they communicate and collaborate by placing colored game pieces shaped like arrows. The arrows indicate how information moves across the functions.	To categorize communication in the flow across development and production functions	Insight into work practices and communication across functions	L
Combine in a storyboard	Then participants collect the visualized context and problem in one drawing and add a plan for the forthcoming activities. The plan can e.g. contain available resources, participants and decision-making competence.	To prepare dissemination to employees and relevant stakeholders not participating	Insight into the problem / gap in customer needs	C

Table 58 (continued)

	Activity	*Purpose*	*Outcome*	*(D) diverging, (L) clustering, (C) converging (S) sharing behavior*
Present the storyboard	Employees from the two functions receive a short (collective) presentation of the scope and plan for the forthcoming activities.	To offer an opportunity for internalization.	Insight into and shared understanding of the problem / gap in customer needs	S
Design Solutions				
Design criteria	Based on the problem clarification, participants set a number of design criteria that describe the knowledgeable (technical) limits the participants should challenge. Multiple sets (set-based) of possible solutions are further developed in rapid prototyping or innovation challenge.	To set up evaluation criteria for solution designs	Insight into the design constraints they are trying to challenge. Insight into work practices across functions.	L
Rapid prototyping	Rapid prototyping is about developing creative collaboration between production and development, which results in many physical ideas for a specific problem (product or process layout). It takes place within a short time frame and can be a way to exploit the creative potential of employees. The method should introduce creative collaboration and principles of collaboration.	To generate ideas for the future in the development process.	A shared understanding of the opportunities for solving the problem. Insight into work practices across functions	D

Table 58 (continued)

	Activity	*Purpose*	*Outcome*	*(D) diverging, (L) clustering, (C) converging (S) sharing behavior*
Innovation challenge	Management poses an innovation challenge for a team of employees from production and development. Different solutions are determined and parts of functionality or user experience are tested. Working intensively toward a specific solution and creating a common goal allows participants to experience how they each contribute with different skills and knowledge to solve the company's challenges.	To generate ideas for future in the development process.	A shared understanding of the opportunities for solving the problem. Insight into work practices across functions	D
Selection	The different solution designs are compared with the design criteria and challenged. It is essential that the ideas chosen should be integrated into existing production processes (see also the next step).	To select solution designs based on design criteria	A shared understanding of the opportunities for solving the problem. Insight into work practices across functions	C
Combine in a storyboard	Then participants collect the visualized context and problem in one drawing and adds a plan for the forthcoming activities. The plan can e.g. contain available resources, participants and decision-making competence.	To prepare dissemination to employees and relevant stakeholders not participating	Insight into opportunities for solving the problem.	C

Table 58 (continued)

	Activity	*Purpose*	*Outcome*	*(D) diverging, (L) clustering, (C) converging (S) sharing behavior*
Present the storyboard	Employees from the two functions receive a short (collective) presentation of the scope and plan for the forthcoming activities.	To offer an opportunity for internalization.	Insight into and shared understanding of opportunities for solving the problem.	S
Implementation				
Prepare implement ation plan	Preparation of an implementation plan allocating resources in relevant functions. Ongoing implementation of two selected changes, either as an integral part of existing production or as a separate project.	To plan and initiate implementatio n of solutions	Structures that ensure integration in work practices	D
Internal progress status	In connection with the implementation - companies conduct internal progress meetings (approximately every 14 days) integrated into normal meeting activity in the workplace	To support the implementatio n process	Structures that ensure integration in work practices	C
Follow-up with DTU	DTU discusses with companies (3 meetings during the period of time)	To support the implementatio n process	Insight into the integrated work practice.	S

Table 58 (continued)

	Activity	*Purpose*	*Outcome*	*(D) diverging, (L) clustering, (C) converging (S) sharing behavior*
DTU interviews	DTU conducts interviews focusing on the process, changes in processes / products and performance	To support the implementation process	Insight into the integrated work practice and the learning process.	S
Evaluation and discussion				
Chronicle workshop	The method consists of three rounds in which I asked a question for reflection. In this case the questions were: 1) What important changes in your daily work have you experienced in connection to (the intervention) UPM3 / since January 1st / this project? 2) What factors have influenced the course of events? 3) How did tools/methods support/hamper the course of events? The participants get 10 minutes to individually reflect on their answers to these questions and write down their reflections on colored notes. Each of the participants then presented his or her reflections to the others. A discussion followed the presentation in each round in which the participants challenge, support or elaborate on each other's comments. The participants organized the notes chronically on the wall, with each round represented by a different color visualizing the three rounds as three lanes	To evaluate and develop shared insight into the process through the program	Insight into the integrated work practice and the learning process.	S

The following codes of conduct were presented to the participants:

- Gather participants with different backgrounds
- Actively engage participants
- Let participants share experiences
- Explain current forms of collaboration between production and development
- Pointing to new forms of collaboration
- Changes are a common process, with both managers and employees participating, to ensure collective support
- Changes should focus on daily practice
- Integration into existing tasks
- The tacit knowledge about problems and solutions must be made explicit
- The change process / project must have equal status with other tasks
- The process must be run by a coordinator who has allocated time
- Progress and results must be visualized

DTU's role along the way was to provide:

- Input for process and observation of the same
- Participation and facilitation of activities
- Processing outcomes and suggestions for priorities and efforts
- Feedback from workshops and presentation of priorities in collaboration with the company
- Meetings during the implementation period with manager and coordinator
- Chronicle workshops providing feedback on process and results

Testing the CII-program in a large manufacturing enterprise in cases A4 and A5

Cases A4 and A5 aimed at testing the CII-program in two pilots. Case A4 aimed at solving a problem in sharing knowledge among technicians in the analysis function. Case A5 aimed at solving problems in sharing knowledge between a composite factory and injection tool development. Table 59 lists completed activities in the two cases.

59. Completed activities in testing the CII-program in cases A4 and A5				
	Case A4	***Period***	***Case A5***	***Period***
Scoping		Jan. 2017		Jan. 2017
Visualize the context map	X		X	
Draw the problem	X		X	
Combine in a storyboard	X		X	
Present the storyboard	X		X	
Clarify the gap		Mar. 2017		Feb. 2017
Design reviews of a process	X		X	
Job swapping / observation	X		0	
Needs and contributions	X		X	
Communication landscape	0		X	
Combine in a storyboard	X		X	
Present the storyboard	0		0	
Design Solutions		Mar. 2017		Mar. 2017
Design criteria	X		X	
Rapid prototyping	X		X	
Innovation challenge	0		0	
Selection	X		0	
Combine in a storyboard	X		X	
Present the storyboard	X		0	
Implementation		Mar. – Apr. 2017		Apr. – May 2017
Prepare implementation plan	X		X	
Internal progress status	X		X	
Follow-up with DTU	X		X	
DTU interviews	0		0	

The senior plant manager of the electronics factory, quality manager and a lean manager participated in scoping the task for case A4. Participants defined the problem of losing flexibility in overlapping technicians' tasks and ability to quickly scale resources when product failures arise. In addition, there was a need for increasing efforts toward failure detection to ensure quality in repair work. The result of the scoping activity was a storyboard visualized below in Figure 43.

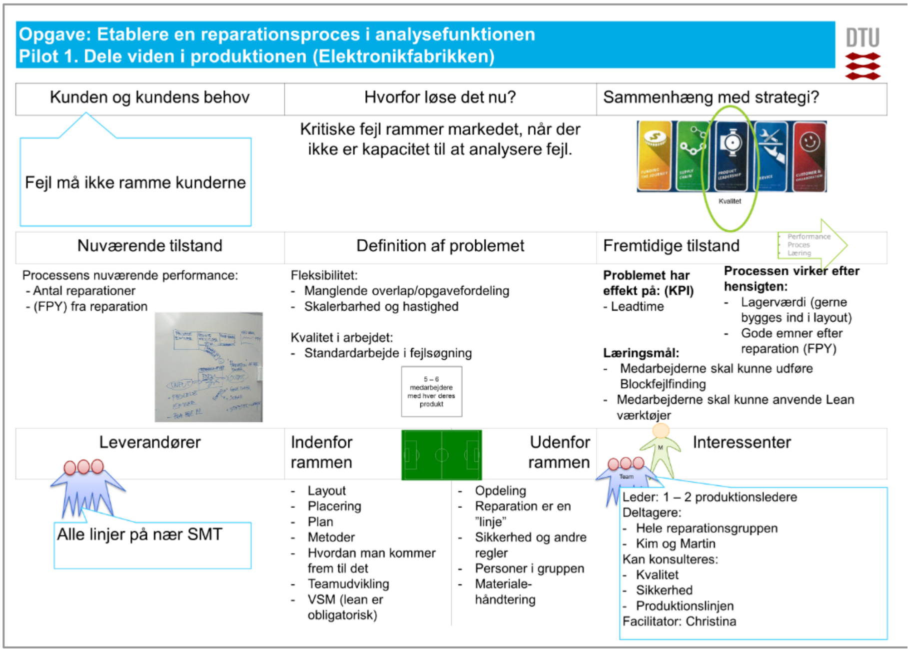

Figure 43. Storyboard from the scoping activity in case A4 (text in Danish).

The designated group worked two and three consecutive afternoons, mostly on the shop floor. When clarifying the gap, the participating technicians described and reviewed the repair processes for the different products and observed each other's work practices. Furthermore, they described their communication with other functions or departments when performing their work. Concurrently they took action to remove all unnecessary tools and products from the work area, thus clearing space for a new layout. As a result, the participants generated 10 suggestions to improve work practices and layout in the department. In the following activities to design solutions, the participants specified criteria for and proposed three different layouts. The participants also designed suggestions for worktable design and for the flow of failed products between production lines and analysis. Furthermore, the participants designed a board and a process for following up on the distribution of workload among technicians and product failures. Participants presented the suggestions to the senior plant manager and successively implemented them. Figure 44 shows the storyboard applied in case A4.

Figure 44. Storyboard applied in the test of the CII-program in case A4.

The most important change for the technicians implied that they flowed between tasks instead of being dedicated to specific production lines (and product families). The new layout includes a designated space for products with failures visualizing workload across product families. Before the change, products were placed near and between the technicians' workplaces that were personalized and dedicated to products. Figure 45 shows the work area before and after the change.

Figure 45. Before and after changing the layout in the analysis department. The change implied that technicians could flow between work tasks according to the demand.

Scoping in case A5 included a lean manager and management representatives from the composite factory, manufacturing support and AME. The participants decided to use a recent development process of an injection-molding tool for a lid as a specific example for the task. This specific development process had faced considerable delays and exposed problems in sharing knowledge between the factory and manufacturing support on one side and tool designers from AME/Technology center on the other. Dialogue in the scoping activity generated the metaphor of the "two-legged chair", where the factory and manufacturing support was missing. Figure 46 shows the storyboard and a drawing of the "two-legged chair" produced during the scoping activity.

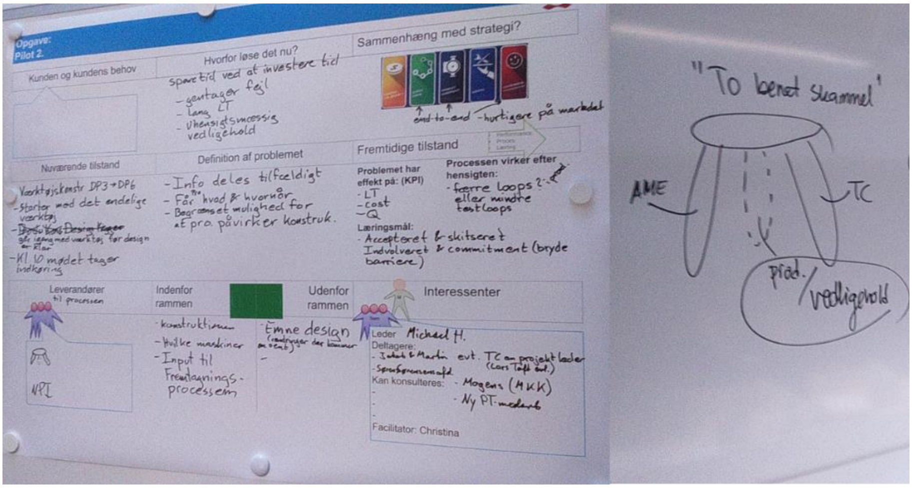

Figure 46. Storyboard for scoping and a drawing of the "two-legged chair" (text in Danish).

Participants in the scoping activity selected a group representing the stakeholders in the process. The group was then introduced to the CII-program and the specific task. The group was subsequently expanded to include a project manager from the specific project and a product designer. The group engaged in revising the specific development process of an injection-molding tool for a lid. Discussion about handing over responsibility in the process revealed inconsistency and supported the fact that the participants generated a shared understanding of the process. Furthermore, one of the participants promoted a functional activity list that he used personally (as shown below in Figure 47). Other participants resisted having such a long and detailed procedure for developing tools.

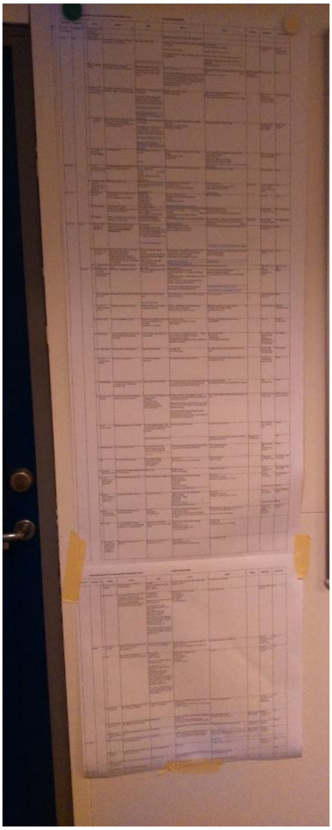

Figure 47. A printout of the functional activity list promoted by one of the participants in case A5.

In the following solution design, the participants shared their experiences about the specific development process as well as development processes in general. However, the participants had no other suggestions that improve the functional activity list. The following activities focused on describing roles and responsibilities for each of the activities in the list. I unsuccessfully requested facts such as lead-times on the specific development process and the number of new tool developments. In parallel with the application of the CII-program, AME held a lessons-learned session about the specific development process and started participating in weekly meetings with maintenance support at the factory. Figure 48 below shows the storyboard and process map applied in case A5.

Figure 48. Storyboard and process map from case A5.

Table 60 lists the purpose, outcome and learnings from testing the CII-program in cases A4 and A5.

60. Purpose, outcome and learnings from cases A4 and A5				
	Purpose	***Expected outcome***	***Outcome***	***Learnings***
Case A4	Reduce lead-time by repairing controls Reduce failures from repair (FPY) Ensure new types of failures are detected and analyzed	Shared understandings about analysis processes and new organizational practices	Technicians gained insight into each other's work practices as a prerequisite for mutual adjustments and coding knowledge into procedures. New layout supported integrating new work practices into the process.	Instant collective action in changing the layout instantly supported the collective thinking and experimentation with prototypes of suggested solutions.
Case A5	Reduce lead-time by reducing the number of problem-solving loops or shortening the loops. Ensure that all relevant stakeholders' knowledge is considered in the process.	Shared understanding about the specific process and creating suggestions for new organizational practices.	Shared understanding of the insufficiencies in the development process and suggestion to develop and integrate the functional-activity list as a new work practice.	Lack of facts and limited experimentation restrained challenge of cognitive maps. Consequently few suggestions for solutions were developed.

Testing the CII-program in a medium-sized manufacturing enterprise – case B3

Case B3 aimed at testing parts of the CII-program in continuation of the activities in case B3. Table 61 contains a list of completed activities in case B4. Activities in case B4 aimed at reducing recurring deviations in order to reduce lead-time and improve product quality.

61. Completed activities in testing the CII-program in case B4		
	Case B4	***Period***
Scoping		Dec. 2016
Visualize the context map	X	
Draw the problem	X	
Combine in a storyboard	X	
Present the storyboard	X	
Clarify the gap		
Design reviews of a process	0	
Job swapping/ observation	0	
Needs and contributions	0	
Communication landscape	0	
Combine in a storyboard	0	
Present the storyboard	0	
Design Solutions		Feb. 2017
Design criteria	X	
Rapid prototyping	X	
Innovation challenge	0	
Selection	X	
Combine in a storyboard	X	
Present the storyboard	0	
Implementation		Mar. 2017
Prepare implementation plan	X	
Internal progress status	0	
Follow-up with DTU	X	
DTU interviews	0	
Evaluation and discussion		May – Jun 2017
Chronicle workshop	X	

The management team scoped the task to focus on projects similar to the project in case B3. The management team discussed the insights about the problems clarified in case B3, especially the inability to distinguish whether a change in information was due to overlapping activities or due to upselling and categorization of deviations. Categorization of deviations was exemplified with the issue that one missing hole in a part might be a small problem, but when 42% of the deviations included holes in parts, then the costs would be considerable. The management team also defined design criteria for the assigned group's suggested solutions. Figure 49 shows the storyboard from the managements team's scoping activity in case B4.

Figure 49. The storyboard from the management team's scoping activity in case B4.

I first introduced the participants assigned to the task in case B4 to the insights gained in case B3 as well as the management team's scope of the present task. I used the two storyboards to support the introduction (as shown below in Figure 50). The group then developed a shared understanding of the meaning of the words applied for the design criteria and planned successive activities to design solutions.

Figure 50. Storyboard from case B3 and scope for case B4 applied in the beginning of case B4.

In the following activities, the group suggested numerous suggestions which they categorized and re-framed in order to develop an overview of the opportunities and to combine the different suggestions. The group then divided in two and developed prototypes for the suggestions. When presenting the prototypes to each other, they frequently collected facts from the deviation system. The group finally decided to present two groups of suggestions to the management team. The participants' process of designing solutions was visualized on a storyboard, as shown below in Figure 51.

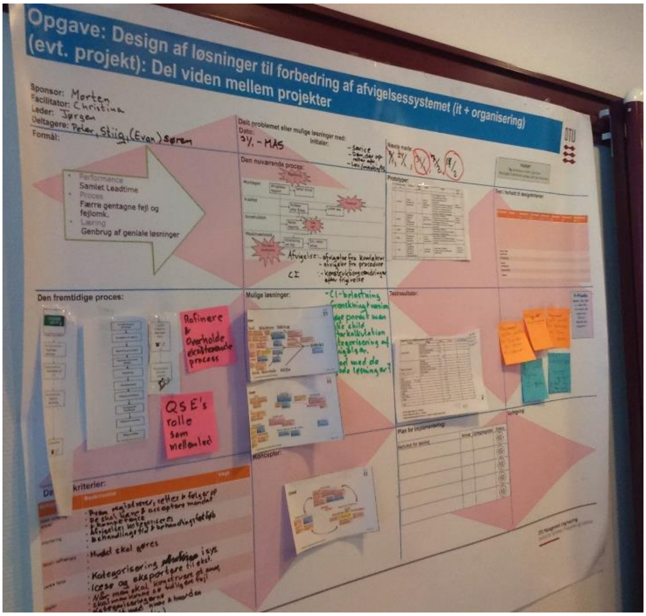

Figure 51. Storyboard visualizing the development process in case B4.

Table 62 lists the purpose, outcome and learnings from testing the CII-program in case B4.

62. Purpose, outcome and learnings from case B4				
	Purpose	***Expected outcome***	***Outcome***	***Learnings***
Case B4	To prevent deviations from recurring in successive projects	Shared understandings about deviation and develop new organizational practices	Participants gained insights into each other's work practices and integrated selected solutions into the existing systems and procedures.	Frequent fact checking challenged participants' cognitive maps and thus provided new insights. Experimentation with prototypes revealed how suggestions could be integrated into existing systems and procedures.

9.5 Summary of applying prototypes and testing the CII-program

The participants in cases A3, A4, A5, B2, B3 and B4 evaluated the work they performed when applying the CII-program. In the evaluation, participants went through their findings, planned the next step and individually filled out a self-evaluation paradigm, in which the participants categorized the type of innovation for suggested solutions. Furthermore, they evaluated the novelty of the solution, scoping of the task and process on a seven point Likert scale. Figure 52 shows the self-evaluation paradigm. The purpose of using a self-evaluation paradigm was to include the participants' own evaluation of the outcome of the activities to supplement the intervention diaries expressing my subjective interpretation of the outcome. The self-evaluation also enables comparison of the outcome across the six cases.

Project/activity:								
Task:								
Target:								
Date:								
Participants:								
Result:								
What kind of innovation is the solution?								
	Business model							
	Network							
	Structure							
	Process							
	Product performance							
	Production system							
	Service							
	Channel							
	Brand							
	Customer engagement							
Novelty		**Low**		**Middle**			**High**	
To what extent …		**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Is the solution new to the function							
	Is the solution new to the company							
	Is the solution radically different than what is seen elsewhere							
	Is the problem solved							
	Is the solution physical and visual at the workplace							
	Is there a system established to follow-up that the solution works as expected							
	Is it documented how the solution is expected to work/be used							
	Is the solution applied as intended							
	Is the solution shared with others							
Scoping		**Low**		**Middle**			**High**	
To what extent …		**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Has the task been clearly defined							
	Has the plan been kept							
	Have the agreed resources been available							
	Has it been clear who had what role							
	Has the group collaborated constructively							
Process		**Low**		**Middle**			**High**	
To what extent …		**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Is several causes to problems forwarded							
	Is several suggestions to methods for analysis of the problem forwarded							
	Is several solutions to problems suggested							
	Is there collected data / tests runs to verify causes							
	Is there collected data / tests runs to verify solutions							
	is knowledge shared about possible solution internally in the company							
	is knowledge shared about possible solution externally of the company							
Comments:								

Figure 52. Self-evaluation paradigm applied in cases A3, A4, A5, B2, B3 and B4.

To compare the six cases, I counted the number of answers for the innovation types and calculated the average for novelty, scoping and process. Table 63 shows the results of the participants' self-evaluations in the six cases.

63. Participants' self-evaluations of applying and testing the CII-program in cases A3, A4, A5, B2, B3 and B4						
	Case A3	***Case A4***	***Case A5***	***Case B2***	***Case B3***	***Case B4***
Innovation						
-Business model				1		
-Network		1				
-Structure		8	2	2	1	2
-Process	2	7	3	1	2	3
-Production system		2				
-Service				1		
Novelty	5.10	4.20	2.92	3.22	2.71	3.89
Scoping	5.06	4.49	5.07	3.60	4.90	5.53
Process	4.33	3.83	3.90	3.93	2.86	5.00
Number of respondents	3	8	3	2	2	3

Figure 53 visualizes the results from the participants' self-evaluation in the six cases. Cases A3, A4 and A5 did not have the same unit of analysis, as cases A3 and A4 took place in the electronics factory while case A5 regarded the composite factory and AME/TC. Furthermore, case A3 applied the factory's own tools and not the prototype of the program. Cases B2, B3 and B4 also did not have the same unit of analysis, even though case B4 was a succession of case B3. Therefore, the result cannot express a progression of the prototypes into the final program. What the result shows is that participants in case A5 rated novelty low, as no suggestions were implemented at the time of evaluation. Scoping however is rated high in cases A3, A4 and A5. Scoping is also rated high in cases B3 and B4. Case B4 rates novelty within the middle range, as here as well no suggestions were implemented. Regarding the process in the six cases, only case B4 results in a high rating. In case B4, the participants had mutual suggestions regarding causes and solutions to the problem.

Figure 53. Visualizing the results of participants' self-evaluations in cases A3, A4, A5, B2, B3 and B4.

I facilitated chronicle workshops as part of the final CII-program's evaluation activity, which includes cases A4, A5 and B4. I had also planned interviews as a follow-up activity, however, it was not necessary to conduct interviews. The chronicle workshops provided rich information regarding the organizational members' insights in the process. Table 64 summarizes the outcome of the chronicle workshops in the three cases.

64. Outcome of the chronicle workshops in case A4, A5 and B4

	Case A4	***Case A5 (Management)***	***Case A5 (Group)***	***Case B4***
Important changes in your work	+Improved communication +Improved flow on failures +Increased focus on work load +Improved collaboration %Less space in work area %Less flexibility	+Clear problem +Openness about challenges +Initiated collaboration (instead of silos) +Shared understanding +Communicatio n	+Increased focus +Created an overview +Increased communication +discovered a problem +Morning meetings and lessons learned %More approach than changes	+constructive dialog with management +breaking down silo's +correcting deviations throughout the process +clarified issues about deviation +better information about projects
Factors influencing course of events	+Concrete output +Desire to improve +Collaboration +Overview	+Clear problem and recognized need +Demand for change +Resources/tim e and the right people +facilitation +Active process +Realized that the problem needs to be solved in collaboration	+Scoping document +Right people +Prioritized resources +Management focus +Coordinator and facilitator +Specific case +FAL-list (solution)	+Increased focus %lack of priority and commitment %too busy %substitution of employees %part results %purpose and results not sufficiently communicated
Tools/methods that support/hamper	+Brainstorming +Group work %Difficult to understand activities	*(question was not asked)*	+RASCI +Consensus seeking slowing progress but enhancing buy-in +Scoping document %Method is not described %Alternative solutions %Generalized structure %Boards	+ opened up for discussions +/% storyboard +Inspiration +/%methods supports but not used enough

Part V Analysis

The purpose of this part of the thesis is to present the analysis of the two empirical sub-questions RQ2 “What challenge cross-functional work practices in product realization in a medium sized Engineer-To-Order respectively a large Make-To-Stock manufacturing enterprise?” and RQ4 “What activities supports integrating new organizational practices in product realization?”. Data collection and analysis method was described in Chapter 7. I presented findings for sub-question RQ2 in Chapter 8 and will now present the analysis in Chapter 10. Respectively, I presented findings for RQ4 in Chapter 9 and present the analysis in Chapter 11.

Chapter 10 Analyzing challenges in two manufacturing enterprises explores cross-functional challenges in a large and a medium sized manufacturing enterprise. The analysis is based on case A1 and case B1 presented in section 8.1 and 8.2. First, I present the analysis in each of the two manufacturing enterprises. Then I explore differences and similarities in a cross-case analysis. The purpose is to understand the relationship between cross-functional challenges and the obvious differences in size of organization and Order decoupling point (Make-to-stock/Engineer-to-order) in the product realization process. Does it make a difference or do they have the same types of challenges? Interestingly, the prevailing difference is that case A1 refer to the organization and its structure where case B1 refer to specific functions when talking about internal stakeholders. They then have in common that they relate cross-functional challenges to the relations among stakeholders, capability of the organizational system and development actions.

Chapter 11 Analyzing organizational learning processes in the CII-program explore activities that facilitate organizational learning processes. The analysis is based on data generated by applications of the CII-program in case A2, A3, A4, A5, B2, B3 and B4 I presented in chapter 9. I apply the 4I framework presented in chapter 4 to analyze the organizational learning processes that took place when I applied the CII-program in the two companies. I first present the analysis of cases within company A followed be the cases in company B. Then I present a cross case analysis of the three cases that include the test of the refined program. In the cases, I identify activities that facilitate Intuiting/attending, Interpreting/experimenting, Integrating and Institutionalizing as organizational learning processes. The cross case analysis show that limited experimentation took place in company A and propose that this can lead to lacking institutionalization of suggested solutions.

10 Analyzing challenges in two manufacturing enterprises

This chapter analyze the cross-functional challenges in case A1 and case B1 presented in section 8.1 and 8.2 to develop an answer for sub-question RQ2:

RQ2: "What challenge cross-functional work practices in product realization in a medium sized Engineer-To-Order respectively a large Make-To-Stock manufacturing enterprise?"

Chapter 2 and 3 presented findings for RQ1 characterizing cross-functional challenges in product realization by workflow and structures, knowledge processes, as well as horizontal and vertical collaboration. In the summary of chapter 8, I related the challenges in case A1 and B1 to these three characteristics. This chapter presents an analysis relating the cross-functional challenges to stakeholders, relations, capability and development actions for case A1 and B1. Stakeholders are the organizational units, internal functions, and designation of occupation that respondents refer to when describing challenges. Relations describes the relationship between stakeholders and characteristic actions in the relationship. Capability refer to competences and capacity of resources (human, technical and production system) that respondents finds challenging. Development actions describes initiatives for developing product realization processes or the production system in general. In the analysis, I see the cross-functional challenges in product realization processes from a production systems perspective. This means that I consider Operations functions the primary stakeholder and include collaboration with development functions to the extent that they influence product realization in Operations. Therefore, I first present the analysis of each case separately followed by a cross-case analysis.

10.1 Analyzing cross-functional challenges in case A1

Case A1 describe challenges in product realization processes as characterized by linear workflows across specialized functions that create, use and process knowledge within functional boundaries and lack alignment across functions.

Stakeholders

Operations and specifically the electronics factory is primary stakeholder. The factories are parallel functions to Manufacturing Support, Supply Chain Management and Technology Center as shown in section 8.1. This functional structure imply extensive cross-functional work processes in the make-to-stock product realization process. Technology is responsible for developing products and processes, while the factory, Manufacturing Support and Supply Chain Management is responsible for daily operations and Shop floor Excellence is responsible for developing continuous improvement capabilities in the organization. Thus, these stakeholders all have a role in product realization in a lifecycle perspective. In addition, they report to the same COO for Operations.

One example of their role in product realizations is the Technology Center who is the development function that introduce new products and implements new production processes or equipment in the factories. E.g. operation managers and production supervisors plan the introduction and implementation with Supply Chain Management, operators in production run new equipment and new products. In addition, technicians handle product failures from new products and coordinate them with the quality function in manufacturing support and other technicians maintain new equipment and ensure that the equipment is running.

From the Lean directors perspective, implementing new technologies might be fancy, however also imply a risk for stability in production. One of the prevailing themes in the Technology Center management team's workshops are "Shop floor readiness" of production equipment. In addition, the handover of responsibility from Technology to the factory and daily maintenance is a topic for tense discussions among technicians at the electronics factory. If the equipment is not sufficiently stable when handing over the responsibility then maintenance technician's workload will increase and the factory can have difficulties in meeting customer demands. Both issues include increases in related costs.

Operation managers and production supervisors refer to a Lighthouse project a Lean leadership project when it comes to developing daily operations. Production supervisors are assigned a lean manager as a coach to support continuous improvement initiatives and action plans. Furthermore, production supervisors are required to follow a daily diary with daily huddles with their employees, peers in the factory and fixed periods for being present at the shop floor for problem solving. There are also structured multi-level follow-up meetings on action plans. The challenge production supervisors mention concerning these structures is the limited time they have left for administrative work such as reading e-mails. One production supervisor mention that he has 45 e-mail from the day before that he has not read yet. Thus, the supervisors still receive many e-mails even though the intention with short daily huddles on various levels is to facilitate coordination in the factory.

There is a lot of interaction between stakeholders in product realization processes, but who is responsible of what when it comes to developing product realization processes? What channels is used for what type of coordination? I would like to close this section with a quote from the Technology director:

> "I think that cross-functional cohesion is a challenge in the constellation we have made."

Relations

The Technology director acknowledge that cohesion becomes a challenge, when the company organize functionally and expect all to concentrate on specialization. It is not sufficient for Technology to have a portfolio of interesting new technologies. Technology cannot succeed unless the new technological inventions are realized on the shop floor. The implementation of new technologies is not sufficiently fast when it comes to the transition from Technology to the factory. From the Technology department's perspective, it is a challenge that the factories focus on deliveries and productivity and are not measured on their contribution to the implementation process.

The Operation manager also see a challenge in aligning expectations in the interface between those who deliver (new products and processes) and those who receive (the factory). These interfaces cause potential tensions between the stakeholders. One example observed is signing-off new production equipment between Technology Center and the factory and the maintenance function. Mutual understanding across functions is a challenge within the factory when it comes to production supervisors' insight into analysis technicians' technical problems in products. Analysis technicians are very skilled people who expects professional feedback.

At a workshop for the Technology Center's management team, one of the participants also suggests that product developers and engineers sit together close to the factory. The technology director talk about including employees from the factory in technology development though the Lean director do not see that the big inventions would come from that point. Shop floor Excellence and Technology are both responsible for developing the production system on behalf of the factories. Thus, they compete for priority in the factory and on the development agenda at management levels within Operations. Furthermore, Shop floor Excellence also challenge Technology on continuous improvement of their work processes by initiating Lean Engineering activities. Shop floor Excellence provide project managers with daily diaries, map development processes and initiate daily huddles in Technology. Technology on the other hand is aware that they have to understand the challenges in the factory so that they can develop new solutions. This means that they would have to change their development process as well as develop Engineers and project manager's competencies and understanding of the factory.

According to the Technology director, Engineering functions and the factory can develop a better understanding of each other thus developing a better understanding the hole when they is located closer to each other. The benefit would be to enable that the right decisions are made on the right level in the organization. This means that making the decisions at a low level in the organization where the expertise is present instead of a high level with sufficient authority. Engineering in Technology also needs to increase their understanding of the context where new technology are used.

Alignment or cohesion is also an underlying topic in the workshops about the future production system. The management team is trying to understand what the future task of the production system would be and what that will mean to them as development functions. However, their point of departure is to describe the present production system and not liberating themselves from the existing. Furthermore, it is interesting to see that they step back from including others from other parts of the organization to provide them with inspiration and other perspectives. The question of including others in the workshop was discussed several times though each time refused.

Development actions

A challenge for the factory is to keep up the pace of constantly taking actions to improve competitiveness. A primary focus area is to improve equipment efficiency in the factory to generate idle capacity and avoid opening a third shift. Initiatives in action plans related to the Lighthouse project supported this focus on isolated optimizations of production equipment. Other objectives is to prevent accidents (safety) and amount of implemented improvement suggestions from employees. Neither of these objectives encourage cross-functional collaboration within the factory or with stakeholders outside the factory.

The Lean director tries to understand Lean's role lacks in the Strategy plan. He finds that everybody must contribute to "Funding the Journey" not just Operations. As the present strategy plan is initiated in May 2015, the new COO was not part of the process developing the Strategy Plan. Lean Engineering is an initiative to improve structured processes, which imply that it is possible to be innovative within a structured process. However, the engineers and project managers are reluctant in constraining the way they work. Shop floor Excellence has initiated Lean Engineering initiatives and introduced Lean Line design where design engineers creates muck-ups of new production equipment together with operators and technicians from the factories.

Capability

Capability is the combination of having the capacity to act and ability or competencies to act. The lack of cohesion on the development agenda consequently challenge the factory on available resources for development activities. Among initiatives for improving the factory's competitiveness, two major activities were moving the electronics factory from one facility to another more modern facility during the summer of 2015 and spring 2016. Simultaneously, 3 – 4 internal Lean managers was running an intensive Lighthouse project in 2015 to encourage an improvement culture. The same management resources are needed to coordinate a Lighthouse project and moving the factory while simultaneously having a vacant operation management position. Furthermore, the Technology function appointed the electronics factory for the present research project.

Within the factory, distribution of workload among technicians is challenged as they refer to each their production supervisor. The operations manager require competent technicians that understand new products and are able to detect quality problems at an early stage.

> "It's one of the things that determines our efficiency on the equipment. We can see that it can be higher if we have better skills. ... [B]oth to get them trained and optimize our training and to have enough of such as technicians at all three shifts. ... [S]ome of it is given by the organization we have here ... with many of our technicians who belong to the production supervisors. "
> (Operation Manager)

Furthermore, operation management question whether there is sufficient staffing in maintenance to deal with problems related to production equipment.

When it comes to competencies, mutual understanding across functions in product realization processes is challenged. Technology mention engineers ability to understand challenges in the factory as an example. As the Technology director comments: “If they don’t know, how can they then make solutions for them?”

Summary

Lean and technology represent two challenges that contradict each other at the factory. Ramping-up new products create variance and disturb Lean efforts for increasing efficiency through stable processes. An ongoing discussion between technicians in Maintenance and developers in Technology regards when a project is finished and ready to hand over to the factory and maintenance functions.

A prevailing theory-in-use is that structured processes and doing the right thing will lead to success. Shop-floor Excellence, Technology and the factory all emphasize following structured process as a means to gain control of a situation. It is seen as a way to manage cross-functional collaboration. Development actions are implemented in top-down process that leaves little space for bottom-up continuous improvements generated by employees. Furthermore, the deep specialization induce difficulties in understanding each other across functions. Consequently, a program that address these challenges can question whether structured processes is in conflict to creativity, cross-functional collaboration and mutual understanding. In addition, a program could address the question whether the demand for increased knowledge sharing is a symptom of insufficient structures that support cross-functional collaboration.

10.2 Analyzing cross-functional challenges in case B

Case B1 describe challenges in product realization processes as characterized by linear workflows that create, use and process knowledge within project boundaries and lacks alignment across projects.

Stakeholders

Engineering functions has a close collaboration with Assembly functions in Engineer-to-order types of product realization. The Assembly function realize Engineering's designs by assembling and testing the equipment before shipping to customers as described in the findings in section 8.2. Together they solve deviations, design changes and ambiguities in design for each project. Thus, cross-functional collaboration and coordination between Operations and Engineering functions are close in the period when Operations assemble and test the equipment on the shop floor. Suppliers and the Machining function produce the parts for the equipment and contribute as stakeholders in the product realization process. The present case study does not include the relationship between Engineering and Sales functions in relation to product realization.

Both Operations and Engineering functions has initiated Lean initiatives to improve workflow and coordination within functions and projects. Employees and managers appreciate the insight and decisions they gained from various status meetings that are one of the outcomes of the lean initiatives.

Relations

The challenges mentioned in interviews and observed in work situations concentrate on deviations and design changes. Both deviations and design changes cause disturbances in assembly work. E.g. as parts already assembled is changed, parts do not fit together or otherwise cause confusion in how to assemble the parts not to mention parts not available in time for assembly. Subsequently these disturbances frustrations generates for technicians and the assembly leader. Presently, Engineering project teams and Assembly focus on solving deviations and design changes for the specific project, and ensure documentation and not coordination across projects. Consequently, designers feel they reinvent the wheel and technicians in Assembly corrects the same deviations repeatedly. One initiative taken to meet this challenge was to position a designer at the Assembly shop floor a few hours each day in the period where technicians assembled the equipment. This creates a short distance between revealing deviations and correcting documentation as well as facilitated cross-functional understanding.

The relationship between technicians in assembly and designers is direct and personal. The technicians often come to the designers and ask questions about the design. The project model also prescribe that one of the designers should be physically present at the shop floor during assembly. A close interaction between technicians and designers ease processes for deviations and changes in design. However, some of the designers are not eager to sit "out there instead of inside the office" while the job is to correct product failures and delay starting on the next project. Other designers sees the close interaction with technicians as an opportunity to learn about the equipment they design and see it materialize from the blueprints. Even though it is an agreed practice to have designers in Assembly, it does not always happen.

Daily status meetings at the shop floor by the machine and pending issues listed on a flip-board is a focal point for the cross-functional collaboration between Assembly and Engineering. The following participates in these daily status meetings: Production manager, production supervisor, assembly leader, project manager, Engineering manager and representatives from production technical function and logistics. This broad representation enable cross-functional coordination and decision-making.

A source of conflict and mistrust between Operation and Engineering is that Engineering release parts and sub-systems before the final design is finished due to time constraints. Designers work overtime and cut corners delivering unfinished work. Consequently, Operations experience rework and deviations during assembly. Thus, workflow overlaps in reality even though the project model illustrates a sequential workflow.

Development actions

The management team questions how much production the company needs to have. The segmentation in Gold, Silver and Bronze has reduced the production set-up in order to be competitive. It can then be a job for suppliers to automate production processes. A nucleus example of a project is point of reference for designing equipment though documentation is still copied from previous projects when designers initiate a new equipment design.

Lean or World Class Manufacturing was initiated in response to a specific customer's request. Working with Lean is to some extent considered constraining for designer's innovativeness. Especially the CEO is reluctant to proceed in a very standardized direction, which he base on previous initiatives with another researcher and his experience of indecisiveness in specific customer's development processes. Simultaneously, the CEO recognize the advantages of Lean when developing structured administrative processes to web-based sales for Anscillary business unit. Anscillary offers partly customized spare parts for existing customers. Individuals otherwise drive development initiatives. Such as s Product Development manager who have initiated documenting workflows, modularizing designs, and developing an internal Wiki as a knowledge management system. Another example of development activities is a Project Forum of project managers developed the project model. It exemplify ways of working and solving needs for differentiation according to business units.

Capability

For Engineering, scaling up and down in resources mean that valuable design knowledge leaves the company when designers are freelancers, laid off, or find other positions outside the company. Even though the company try to compensate by having a pool of freelancers, and from time to time hire laid off designers, it is related to uncertainty for a designer not to be assigned to a project. Working in a matrix organization disperse specialized design knowledge and makes it difficult for designers to clarify how other designers have solved similar design problems in other projects. The workload and work-life balance is an issue for project managers as they talk about stress at meetings. Project managers admit that they cut corners when lacking resources or time in projects. Consequently, they risk that deviations emerge in Assembly.

Management recognize project managers for their design knowledge, for their relationship with customers, and for their ability to finish project on time within budget. However, the management team emphasize different elements due to their function. Furthermore, they question what competencies they will need in the future and to what extent Lean could reduce their ability to be good in what they usually excel.

Summary

Collaboration between Engineering and Assembly represent challenges in structuring overlapping workflows in projects. Contradictions for the designer is that they are expected to deliver innovative maybe even impossible solutions and still meet customer's deadlines and the calculated budget. These contradictory demands and overlapping workflows expose a need for structures where solutions in previous projects are accessible in an easy way. Thus, support the expressed need for increased knowledge sharing. However, the project model assume that projects are discrete events and does not take coordination and collaboration across projects into account.

A prevailing theory-in-use in case B1 is that categorizations in production and project model meets different needs for standardization. Such an example is the categorization of parts into gold, silver and bronze. This categorization, though, lead to concurrently reducing the amount of internal produced parts. Subsequently, the categorization eliminate incentives for initiating development actions in Operations that has a long-term focus on production setup and promote cost cutting. However, the inability to ensure structures that correct deviations restrain cutting cost in Operations. Incentives in Engineering follows the discrete projects thus restrain learning from previous and other ongoing projects.

10.3 Cross-case analysis

Case A1 and B1 exemplify that challenges are different in large make-to-stock compared to a medium sized engineer-to-order manufacturing enterprise. Case A1 show that solving problems by structuring processes are insufficient for cross-functional collaboration. Case B1 show that fragmented problem solving in close cross-functional collaboration are insufficient for collaborating across projects. The sources of these challenges though remain similar. Table 65 show the sources of challenges in case A1 and B1.

65. Sources of challenges in cross-functional work practices in product realization in case A1 and B1		
	Case A1	**Case B1**
Stakeholders	Abstract and distant	Specific and close
Relations	Structured processes	Personalized collaboration
Development actions	Stabilization versus new products and processes	Customization versus standardization
Capability	Lack of coordination across functions	Cutting corners squeeze time in production

Stakeholders in case A1 are distant in the functional specialized organization structure and the stakeholders refer to each other in an abstract way. Stakeholders refer to the functions or departments instead of being specific on the issues they deal with. Operations and development functions talk about “them and us” that cause distance between the functions and reduce incentives for involving each other in development activities. Then structured processes becomes a legitimate way of handling coordination across functions, but still it is the development functions that plan the structured processes with limited involvement from operations. Development activities designed by development functions then expose ambiguous and contradicting goals for stabilizing versus new products and processes. These ambiguous and contradiction goals are interpreted as lack of cohesion by stakeholders and restrain the ability to make cross-functional decisions on low levels in the organization.

Case B1 on the other hand has close relationship between Engineering and Operations on specific issues in the projects. Stakeholder’s collaboration with each other is personal as they mention each other by name on the shop floor. The frequent presence of designers in Assembly and technicians in Engineering offices indicate a short distance between the functions. The structures related to projects also ensure that relevant stakeholders are involved and authorized to make decisions. However, case B1 also exemplify ambiguous and contradicting goals for customization of the equipment versus standardization that could increase project efficiency. Development activities in case B1 do not address these ambiguous and contradicting goals. On the contrary they over emphasize goals what restrain developing the necessary structures. Consequently, designer cutting corners and squeezing time for production erode capabilities to develop cross-functional work practices.

Challenges in case A1 and B1 is then not just about sharing knowledge. Insufficient knowledge sharing is merely a symptom of lacking work practices for collaboration across functions and projects and cross-functional collaboration in developing these work practices.

11 Analyzing organizational learning processes in the CII-program

In analyzing the organizational learning processes, I apply the 4I framework and focus two relationships. First, I identify activities facilitating the organizational learning processes in the cases. Second, I identify and input/output of the organizational learning processes. I will do that across A and B cases before doing a cross-case analysis. The purpose is to provide an answer for RQ4:

RQ4: What activities supports integrating new organizational practices in product realization?

I divided the cases into two sets, one for each company. For each of the two sets of cases, I first present the facilitating activities that occurred in the cases. Second, I describe present inputs and outputs from the facilitating activities. Third, I present the organizational learning processes as they occur in the program.

11.1 Analyzing organizational learning processes in case A2 – A5

Case A2 include two breakdown meetings and a challenge that follows procedures as accustomed in the factory. As such, case A2 represent everyday learning opportunities for organizational members across functions. A similar learning opportunity is case A3 that include a problem solving activity following accustomed procedures. Case A2 and A3 include a relatively short course of events compared to testing the program in case A4 and case A5. Table 66 show the activities that facilitated organizational learning processes in case A2, A3, A4 and A5.

66. Activities facilitating organizational learning processes in case A2 - A5				
	Case A2	**Case A3**	**Case A4**	**Case A5**
Challenging cognitive maps	X	X	X	X
Collective action	0	X	X	0
Collective thinking	X	X	X	X
Communicate	X	X	X	X
Dialog	X	X	X	X
Inquiry	X	X	X	X
Reflection	X	X	X	X
Shared Meaning	0	0	X	X
Storytelling	0	0	0	0
Visualization	X	X	X	X

I identified activities such challenging cognitive maps, collective thinking, dialog, and visualization in all four cases. One example of challenging the cognitive maps comes from case A5 where mapping the past design process for a specific lid revealed both organizational inadequacies (such as specialists leaving the project) as well as different work practices in such as process. According to the participants, the source of these differences was due to insufficient processes. In case A2, A3 and A4 challenging cognitive maps also include observations on the shop floor in the factory where the work processes takes place. Visualizations support the challenge of cognitive maps and participants understanding of work practices by externalizing participant's prior experiences and knowledge. Involving others outside the group of participants also provided further perspectives on the specific issues. Between the interventions in the program, a designer e.g. inquired what procedures colleagues was using. Collective thinking includes activities such as brainstorming and categorization that comes with the program. The purpose of brainstorming is to support divergent thinking and open up for other options than the ones the participants already know and use as explanations to root causes and solutions. Categorization is an activity to organize the ideas that comes out of the brainstorming activity. Visualizations and collective thinking provided a foundation for equal dialog between the participants. Interestingly, participants in case A2 and A5 did not initiate collective actions. In case A2, the participants identified problems during the "challenge" that did not lead to action. The result of case A5 was further specification of a process and negotiation more that collectively changing work practices.

The activity reflection is to some extend related as I encouraged reflection in the beginning of the day as part of the program. I could e.g. ask what has happened since yesterday or as in case A4 where I at the end of the day posed reflective questions that I would ask the following morning. In case A2 and A3 reflections was primarily my own and can as such not be related to the actual activities. Case A5 include reflections that I had while observing the scoping session.

Table 67 shows input and output of the facilitating activities in case A2, A3, A4 and A5. Data do not distinguish input and output of the facilitating activities while output of one activity very well could be input to the next. There are considerable differences between case A2 and A3 on one side and case A4 and A5 on the other side.

67. Input and output in case A2 - A5

Input and output	Case A2	Case A3	Case A4	Case A5
Cognitive maps	X	X	X	X
Conversation or dialog	X	X	X	X
Diagnostic systems	0	0	0	0
Experiences	X	X	X	X
Images	X	X	X	X
Insight or knowledge	0	0	X	X
Interactive systems	0	0	0	X
Language	0	0	X	0
Metaphors	0	0	X	X
Mutual adjustment	0	0	0	0
Routines	X	X	X	X
Rules and procedures	0	X	X	X
Shared language	0	0	X	X
Shared understanding	X	X	X	X
Structures	0	X	X	X
Suggestions or opportunities	X	X	X	X

There was a limited use of diagnostic systems and interactive systems (only in case A5). In case A5, participants consulted explicit procedures on the company's intranet to understand what was supposed to take place in the work processes.

The development of cognitive maps gives the participants a shared understanding of the work processes, the problems and events in relation to what happed in the specific task in focus. Collective maps comes out conversations or dialog between the participants, sharing experiences of the specific task and images drawn on boards or created with post-its. A few metaphors was mentioned such as “rolling specifications down the hill” in case A5 indicating throwing-over-the-wall practices in the work process (product realization process). Another metaphor in case A5 was “a two legged stool” (illustrated in Figure 54) that became an image for aligning AME engineering injection molding tools, (TC) manufacturing and testing the injection molding tools with production and maintenace that recieved the injection molding tools. These metaphors help the participants develop a cognitive map and shared understanding of the problems they were trying to solve.

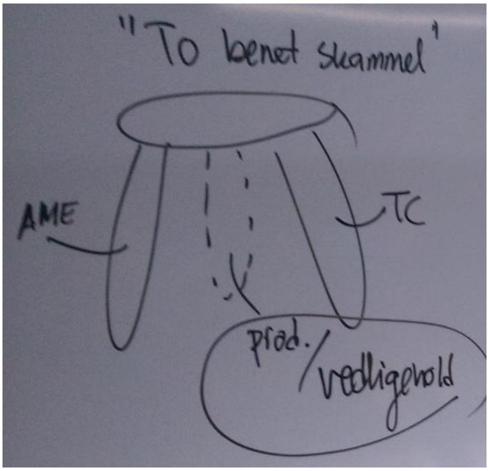

Figure 54. A "two legged stool" a metaphor for aligning AME engineering injection molding tools, TC manufacturing and testing the injection molding tools with production and maintenace that recieved the injection molding tools.

I found limited evidence of participants developing and sharing language in the cases. As such, further analysis is needed to verify whether developing a shared language facilitate organizational learning processes.

Structures such as organizational structures and physical layouts, routines, rules and procedures was both input to and outcome of activities in all of the cases. Discussion, dialog and inquiry shape a shared understanding of the situation as it is and participants suggesting changes in structures, routines, rules and procedures. Participants subsequently implemented some of these suggestions. The cases A2, A3 and A4 that took place in the factory, implemented changes concurrently with applying the program. The suggested changes in procedures in case A5 require negotiating tests of the changes across more functions than those represented in the program.

Participants revealed the insights they gained in the chronicle workshops in case A4 and A5. As an example in case A4 the participants stated that they had gained overview of the workload in the new layout and that, it was helpful to follow their colleagues' ways of working. These insights can be difficult to detect if not explicated in an evaluation or reflection activity. Similarly, participants describe how they now try to even out imbalances in workloads by helping each other in case A4. This exemplify mutual adjustments as an outcome of the learning process.

Table 68 relates facilitating activities within the organizational learning processes to case A2, A3, A4 and A5.

68. Activities facilitating the organizational learning processes across case A2, A3, A4 and A5

	Intuiting	*Attending*	*Interpre-ting*	*Experim en-ting*	*Integrati ng*	*Instituti o-nalizing*
Challenging cognitive maps	X	X	X	0	X	X
Collective action	X	0	X	0	X	X
Collective thinking	X	X	X	0	X	X
Communicate	X	X	X	0	0	0
Dialog	X	X	X	X	X	0
Inquiery	X	X	X	0	X	X
Reflection	X	X	X	0	X	X
Shared Meaning	0	0	X	0	X	X
Storytelling	0	0	0	0	0	0
Visualizing	X	X	X	0	X	X

Attending to potential conflicts in case A5 relates to the difficulties that had occurred in the specific task (developing an injection mold tool for a lid). There had been delays and difficulties in meeting the specified quality. In addition, organizational changes had disturbed the normal routines and the participants seemed to avoid blaming each other or fueling further conflict. In case A4, attending to potential conflicts relate to the first and discontinued application of the program. In that sense, it was a conflict between the Senior Plant Manager or lean manager and me as facilitator. However, in case A4, the Senior Plant Manager was also aware that the participating technicians could react negatively to the organizational change that unified the technicians in one unit.

Intuiting, interpreting and integrating processes show an expected pattern where activities has facilitate these organizational learning processes. Activities such as dialog and challenging cognitive maps facilitate that participants explicate their intuitions and making them available for interpretation in the groups. In case A5 for example, where a dialog between participants from AME and Maintenance support about production set-ups that gives rise to proposing that the factory increasingly builds on standardized and flexible concepts. The consequence can then be that the equipment need for injection molding the specific lid becomes too expensive for the factory. Further dialog about the topic revealed that a tool designers decisions might be in conflict with the factory's overall strategy for the production set-up.

Institutionalizing is the implementation part of the changes. Case A2, A3 and A4 managed to implement some of the suggested changes. Case A4 lacked sharing the solutions and implementations with others; at least as part of the program. The lack of implementation in case A5 was partly due to the complexity of the changes that involved many stakeholders across functions.

More interesting is the limited experimentation in case A2, A3, A4 and A5. Participants talked about experiments or try-outs in connection to the breakdown meetings in case A2. Otherwise, the prevailing practice was to plan and complete activities. Participants did follow-up on initiated activities, though they focused on whether the activities was completed and not whether the activities improved performance or solve the specific problem.

11.2 Analyzing organizational learning processes in case B2 – B4

Participants understanding of the problem evolved through the cases B2, B3 and B4. Different organizational members participated throughout the tree cases. However, one group in case B2 shared their findings of one case with representatives from the next group. The problem in all three cases was phrased as improve sharing knowledge between projects with the purpose of reducing engineering hours in case B2 and reducing recurring deviations in case B3 and B4. Both engineering hours and recurring deviations influenced product quality and cost. Cross-functional participation was gained in case B3 and B4 where the participants represented both Assembly and Engineering. In all three cases activities such as challenging cognitive maps, collective thinking led through dialog or inquiry, to achieve a point where decisions or conclusions were made. The participants visualized their cognitive maps and challenged them with factual data used and involved others in their study of the specific problem and possible solutions.

As table 69 show, the participants in case B2, B3 and B4 applied most of the different activities that facilitate organizational learning processes while solving their designated task. Storytelling will need further analysis to establish examples in data.

69. Activities facilitating organizational learning processes in case B2, B3 and B4

	Case B2	Case B3	Case B4
Challenging cognitive maps	X	X	X
Collective action	X	0	X
Collective thinking	X	X	X
Communicate	X	0	0
Dialog	X	X	X
Inquiry	X	X	X
Reflection	X	X	X
Shared Meaning	X	0	X
Storytelling	0	0	0
Visualization	0	X	X

All input and output elements was identified throughout the three cases. Most strongly, the participants gained shared understanding of the problem and developed cognitive maps of the problems, they were trying to solve and the opportunities for solutions. They also gained insights into each other’s work practices. In addition, the organizational members participating in the cases gained insight into how their own work practices consequently influenced other functions. As shown in table 70 there was a few examples of language and metaphor to gain shared language. Data also exemplify mutual adjustments.

70. Input and output of the facilitating activities in case B2, B3 and B4

	Case B2	Case B3	Case B4
Cognitive maps	X	X	X
Conversation or dialog	X	X	X
Diagnostic systems	0	0	X
Experiences	X	X	X
Images	X	X	X
Insight or knowledge	X	X	X
Interactive systems	X	X	X
language	0	X	X
Metaphors	X	0	X
Mutual adjustment	X	0	X
Routines	X	X	X
Rules and procedures	X	X	X
Shared language	X	0	X
Shared understanding	X	X	X
Structures	X	X	X
Suggestions or opportunities	X	X	X

As an example of developing a shared meaning, the participants in case B4 discussed the meaning of the design criteria set be the management team: clear roles and responsibilities, prioritization, independent on individuals, delivering facts and searchable. Another example of an activity facilitating shared meaning was the project manager and a designer in case B2 sharing their experience from designing equipment for previous projects and marking critical parts on a drawing of the equipment.

In case B4, participants used the quality system actively as part of the activities to make inquiries for factual data about deviations. This exemplify a diagnostic system as input. When the participants discussed sharing information about deviations across functions, the quality system functioned as an interactive system in the work processes. When the participants discussed roles and responsibilities in using the system the outcome was suggestions to rules and procedures. As they formalized their suggestions to rules and procedures, the participants experimented by using examples from the quality system.

The participants in case B4 used gold, silver and bronze as a metaphor when they developed a categorization for handling deviations. Gold, silver and bronze was a categorization the company applied for prioritizing parts they manufactured themselves. As such, the participants used the metaphor to develop a shared language for categorizations. In case B2 participants used a “bible” as a metaphor for a compilation of the rules and procedures designers should follow.

Organizational members was aware of the tension between Operations and Engineering throughout the three cases. The tension stemmed from ambiguous goals of improving efficiency in the projects exemplified with recurring deviations while persistently avoiding standardization. The participants made experiments through all three cases and implemented several of the suggested solutions.

Table 71 show activities that facilitate organizational learning processes across the three cases B2, B3 and B4.

71. Activities facilitating the organizational learning processes across case B2, B3 and B4

	Intuiting	*Attendin g*	*Interpre-ting*	*Experim en-ting*	*Integrati ng*	*Instituti o-nalizing*
Challenging cognitive maps	X	X	X	X	X	X
Collective action	X	0	X	X	X	X
Collective thinking	X	X	X	X	X	X
Communicate	0	X	0	0	0	X
Dialog	X	X	X	X	X	0
Inquiery	X	X	X	X	X	0
Reflection	X	X	X	0	X	X
Shared Meaning	0	X	X	X	X	X
Storytelling	0	0	0	0	0	0
Visualizing	X	0	X	X	X	0

In case B4, the participants attend specifically the differences between deviations and change information’s. Deviations from expectations are failures that influence the product either directly or indirectly. Change information’s are changes in product design that can stem from additional functions the customer demands and pays. However, change information’s can also emerge when designers initiate some parts before they finalize the design. Then Assembly perceive change information’s as if the designers has not done their part of the job before initiating manufacturing of parts. Both the Machining department and suppliers manufacture parts and might not notice differences on the blueprints from one project to the next. Members of the logistics department and a supervisor from Machining mentioned such situations.

Another tension that the participants openly discussed in case B4 was how many deviations was referred to Engineering work. These deviations could be errors in blueprints or part lists. The amount of deviations stemming here from was a surprise to a participating designer. Deviations registered in the quality system was usually handled by the project managers who did not sum up the amount of deviations in a project. In case B2, one designer urge his colleagues to raise a flag whenever something puzzles them in each other’s blueprints.

As an example of experimentation in case B3, a participant made and inquiry into the quality system to find the number of deviations in the specific project and thus relating the discussion to actual fact and data. In case B4 the experimentation related e.g. to finding out whether the existing quality system could handle prioritizations of deviations. Another example in case B4 was applying the suggested categories on registered deviations for the specific project thus challenging further the cognitive maps.

Participants implemented thus institutionalized changes in all three cases. The case B2 the project team implemented the project information sharing board they had designed and to some extend initiated midday five minutes coordination meetings within the project team. The project manager saw these meeting as important for him both to ensure coordination but also to sense the spirit or mood in the group. Case B3 made some smaller adjustments e.g. the quality manager experienced that there was more text describing deviations in the quality system. The following case B4 implemented the categorization of deviations and in this way institutionalized new rules and procedures.

11.3 Cross-case analysis of case A4, A5, and B4

I the following, I present and analysis across the three cases where the refined CII-program was tested. The purpose of the CII-program is to facilitate organizational learning processes while solving problems in cross-functional work practices and integrate them into product realization processes. Testing the program in case A4, A5 and B4 included activities such as challenging cognitive maps, collective thinking, communication, dialog, inquiry, developing a shared meaning and visualizations as listed in table 72. Collective action was not taken in case A5 due to the complexity of the solution, In that case, dialog continued and participants repeatedly shared their experiences. The CII-program did not include activities the deliberately supported storytelling and further analysis is needed to find indications in data.

72. Activities facilitating organizational learning processes in case A4, A5 and B4 where the CII-program was tested

	Case A4	Case A5	Case B4
Challenging cognitive maps	X	X	X
Collective action	X	0	X
Collective thinking	X	X	X
Communicate	X	X	X
Dialog	X	X	X
Inquiry	X	X	X
Reflection	X	X	X
Shared Meaning	X	X	X
Storytelling	0	0	0
Visualization	X	X	X

Challenging cognitive maps through observations and fact finding was prevalent in case B4. case collected limited facts and data in their observations, which did not occur in case A5. I (in the role as facilitator) requested facts and data that could describe the work processes in focus and show whether implemented solutions delivered targeted improvement. However, it was not clear whether these data existed; they were in any case not delivered in case A4 and A5. Interestingly, there was also a lack of collective action in case A5, which indicate that there was less ground for moving from thinking to action.

Does experimentation through observations and fact finding in diagnostic systems or interactive systems promote collective action and institutionalization? That could be a question for further analysis. Table 73 and table 74 show that all the expected inputs and outputs was identified in case B4. The use of diagnostic and interactive systems as well as mutual adjustments was not identified in case A4. Case A5 lacked use of diagnostic systems and language and did not gain insight or knowledge as well as mutual adjustments. Thus, no experimentation and institutionalization was identified in case A5.

73. Input and output of the facilitating activities in case A4, A5 and B4

	Case A4	Case A5	Case B4
Cognitive maps	X	X	X
Conversation or dialog	X	X	X
Diagnostic systems	0	0	X
Experiences	X	X	X
Images	X	X	X
Insight or knowledge	X	0	X
Interactive systems	0	X	X
language	X	0	X
Metaphors	X	X	X
Mutual adjustment	0	0	X
Routines	X	X	X
Rules and procedures	X	X	X
Shared language	X	X	X
Shared understanding	X	X	X
Structures	X	X	X
Suggestions or opportunities	X	X	X

74. Organizational learning processes across case A4, A5 and B4

Organizational learning processes	Case A4	Case A5	Case B4
Attending	X	X	X
Intuiting	X	X	X
Experimenting	X	0	X
Interpreting	X	X	X
Integrating	X	X	X
Institutionalizing	X	0	X

Part VI Discussion and conclusions

The purpose of this final part of the dissertation is to explain findings and contributions from this research project. Findings show that cross-functional challenges are characterized by workflow and structure, knowledge processes as well as horizontal and vertical collaboration. The sources to these challenges are found in stakeholder's relationships across operations and development functions, ambiguous or contradictory goals for development actions that restrain capabilities for developing cross-functional work practices. Findings also identify activities that facilitate organizational learning processes thus extend the 4I framework. Case studies of a probe-and-learn process provide insight into the design process of a CII-program. Finally, the research propose a CII-program for continuous improvement and innovation of product realization processes. In this part of the dissertation, I first discuss findings of the overall research question and the four sub-questions. I then conclude the research by proposing theoretical and practical contributions before I end the thesis by suggesting agenda for future research.

Chapter 12 Discussion explain the findings for the main research question and each of the four sub-questions. An overall issue in research for this project has been that literature is split in either product and process development or production thus limiting literature about collaboration across functions in product realization. Furthermore, limited literature study organizational learning processes in such cross-functional contexts. Findings from this research extends this limited literature, provide in-depth case studies of challenges in cross-functional work practices and propose a CII-program to resolve such challenges.

Chapter 13 Conclusions summarize my contributions to theory and practice as well as indicating implications for practice, limitations for research and propose an agenda for future research. This research provide theoretical contributions to the intersection between operation management, knowledge management and organizational learning by studying challenges in and integration of cross-functional work practices in product realization. The application of a probe-and-learn design process suggest new alleys for collaboration between researchers and practitioners. In addition, this research offer inspiration to practitioner that can help identify and solve challenges in cross-functional work practices. Organizational members though need to pay attention to implications that can restrain the gains from applying a CII-program. More applications of the CII-program can lead to further refinements. The proposed agenda for future research thus include studying organizational learning processes in cross-functional contexts, product realization as a system and challenges in collaborative research.

12 Discussion

In the following, I explain the findings in this research project. I begin with a general discussion on product realization that point toward turning high-level challenges into low-level problems that are manageable for organizational members. I then summarize the findings for each of the four sub-questions and finally the main research question.

12.1 General discussion on product realization

Product realization is a knowledge heavy context that imply multidisciplinary and cross-functional collaboration to perform. Thus, managing product realization processes include high-level decision-making, which restrain low-level problem solving across functions in product realization. Findings from this project suggest that low-level problems can be symptoms of high-level imbalances or inconsistencies. E.g. when Technology and Lean specialists neglect involving operations functions such as the factories and manufacturing support functions in case A1. Similarly, when inconsistency or indecisiveness regarding the degree of standardization in products and workflows results in recurring errors and low efficiency in case B1. Converting such challenges into low-level problem-solving tasks could enable clarification of the problems and experimentation that return valuable insights to management.

Managements scoping process in the CII-program support managing the boundary between high-level decision-making and low-level problem solving. The other activities in the CII-program facilitate a creative problem solving process for multidisciplinary and cross-functional participants. Findings show that group’s ability to span both organizational and knowledge boundaries are crucial for the CII-program. The discussion indicated above regards managing horizontal and vertical coordination and collaboration in product realization processes as well as continuously improving and innovating product realization processes.

12.2 Discussion on cross-functional work practices in product realization

In the literature study in Chapter 2, I found that workflow and structures, knowledge processes and coordination characterize cross-functional work practices in product realization. Workflows and structures in product realization is characterized by parallel workflows and mutual interdependence across functions. The challenges for work practices in product realization processes is then to develop multi-level systemization and cross-functional integration that promote early involvement and prevent “throwing it over the wall” workflows. Knowledge processes is characterized as requiring management of knowledge boundaries (novelty) and knowledge across organizational boundaries. Knowledge processes are challenged by IT-systems that process explicit knowledge though depends on investments in generating content. Additionally challenging is for knowledge processes is reviews, teams and other types of involvement that process tacit knowledge. However, companies risk that knowledge remain individual and follow individuals when leaving for other occupations. Dependency on multidisciplinary coordination also characterize crow-functional work practices in product realization. The challenge in coordination is to collaborate in a climate with ambiguous or conflicting goals.

Workflow and structures

Literature promotes parallel workflows to reduce time to market (Clark & Fujimoto 1991; Liker et al. 1996; Valle & Vázquez-Bustelo 2009; Saunders et al. 2014). Working in parallel require that stakeholders such as designers, engineers and technicians integrate their workflows across functions (Clark & Fujimoto 1991; Liker et al. 1996; Yasumoto & Fujimoto 2005; Lu & Botha 2006; Valle & Vázquez-Bustelo 2009; Vroom & Olieman 2011; Saunders et al. 2014). Literature also suggest ways of achieving this integration through early involvement of relevant stakeholders in reviews (Valle & Vázquez-Bustelo 2009) or cross-functional teams (Lu & Botha 2006; Rauniar et al. 2008). Conceptualizations such as lean product and process development apply set-based concurrent engineering that imply standardizing products into sets or modules (Liker et al. 1996; Morgan & Liker 2006). Concurrently developing these sets in parallel creates competition between solutions that can substitute each other (Valle & Vázquez-Bustelo 2009). This means that literature provides methods and approaches for reducing time to market but there is also implications.

Case studies in the American automotive industry dominates the field (Carlile 2004; Rauniar et al. 2008; Saunders et al. 2014; RAUNIAR et al. 2017) together with Japanese carmakers in America (Morgan & Liker 2006) and comparisons between American and Japanese carmakers (Clark & Fujimoto 1991; Liker et al. 1996). However, Yasumoto and Fujimoto (2005) found that the studied Japanese manufacturing firms were likely to stick to cross-functional integration for product and process development regardless of product characteristic. Cross-functional integrations is effective in developing complex and novel products, but disadvantageous in other types of product development (Yasumoto & Fujimoto 2005). The downside of cross-functional integration is over-specification and high costs that hinders streamlining design activities (Yasumoto & Fujimoto 2005).

A prevailing approach to product development is lean product development that founds on Toyota's product development system. In a longitudinal case study, Karlsson and Ahlstrom (1996) study supporting and hindering factors when companies implement lean product development in a European manufacturing company. Karlsson and Ahlstrom (1996) emphasized supplier involvement, concurrent engineering[7], cross-functional teams, integration rather than coordination, heavyweight team structure and managing project strategically through visions and objectives as distinguishing lean product development from other approaches. Findings from this case study showed following hindering factors:

- Focus on the R&D department in development creates difficulties in achieving cross-functional integration
- Concurrent Engineering is paradoxical to the individual engineers
- Coordination of the lean project creates a time-consuming meeting activity
- Requests for detailed design specifications disturb the visionary-led projects

[7] Karlsson and Ahlstrom (1996) use the expression simultaneous engineering and consider it equal to concurrent engineering.

- Ambitions to maintain a flexible relationship with suppliers coupled with a demand for known costs, obstructs a black box engineering relationship.

Supporting factors in implementing lean product development Karlsson and Ahlstrom (1996) found:

1. Lean buffers in schedules.
2. Close cooperation with a qualified customer.
3. Competence of individual engineers.
4. Top management commitment and support.
5. Regular gatherings with management representatives from different functions.

Another more recent case study (Helander et al. 2015) in companies of different size and industry found that lean product development had positive effect on quality, reduced disturbances, reduced slack time as well as improved communication and awareness. On the other hand, lean product development had a negative effect on creativity and reduced skunk work (Helander et al. 2015).

The approaches and methods suggested in e.g. lean product development assumes that cross-functional integration is a necessity in product realization. This is an assumption that literature supports. However, conceptualized solutions promote “doing it right” more than understanding the inherent problems the suggested solutions are supposed to solve. Alternatively, contingency approaches combine approaches to product realization, manufacturing strategy, product complexity/novelty and competition. Hill (2000) propose a model for aligning corporate objectives, marketing strategy and manufacturing strategy including infrastructure and process choice. Clark and Fujimoto (1991) describes contingency in product development organizations across cases in American, Japanese and European automotive industry. Clark and Fujimoto (1991) ranked the cases according to performance, project strategy, patterns of organization and manufacturing capability. Furthermore, Clark and Fujimoto (1991) suggested four modes of integration:

1. A functional structure with specialized engineers that has limited overall responsibility for the total product. Coordination is achieved through procedures, rules, specifications and meetings or other direct contact.

2. A lightweight product manager structure where the functional structure is combined with a product manager who coordinates development activities.
3. A heavyweight product manager structure where the product manager has more direct access to the engineers working on parts of the project.
4. A project execution team where engineers from the functional structure is assign to projects with the product manager as project manager.

Clark and Fujimoto (1991) also suggests five different workflows for integrating development activities in product development:

1. A traditional sequential approach with unilateral transfer of complete blueprints
2. A high bandwidth (face-to-face) technology transfer of design information
3. Overlapping activities with fragmented release of preliminary information transfer
4. Overlapping activities with mutual adjustments in a bilateral flow
5. Overlapping activities with early downstream involvement with knowledge exchange prior to development activities.

Another observation in literature related to workflow and structure is that mutual inter-dependence across functions require multi-level systemization of work practices in product realization processes. Pisano & Wheelwright (1995) observe that managers can introduce new products rapidly by building organizational capabilities for process development and integrating process development in the product development lifecycle. As product-lifecycles shortens, large changes in both products and production processes will happen more frequently. This draws attention to improving processes that develops product and production as well as the change process itself. Improving processes and change processes is studied by Adler et al. (1999) showing that Toyota consider product changes in manufacturing as meta-routines to store knowledge gained from previous product changes. Likewise suggests other scholars (e.g. Nelson, 1982) that routines can be changed and even invented through meta-routines (Nelson and Winter 1982, Volberda 1996, Grant 1996).

Morgan & Liker (2006) describes three categories of standardization within product and process development; design standardization, process standardization and engineering skill-set standardization. Design standardization comprise standardization of product or component design and architecture. Process standardization involves standardizing tasks, work instructions and sequences of tasks in development processes. Engineering skill-set standardization comprise standardizing skills and capabilities across engineering and technical teams.

Consequently, I add the following dimensions to the element of workflow and structures listed in table 75.

75. Elements and dimensions describing workflow and structure for cross-functional work practices in product realization

		References
Modes of integration		(Clark & Fujimoto 1991)
1	Functional structure	
2	Lightweight product manager structure	
3	Heavyweight product manager structure	
4	Project execution team	
Workflow integration		(Clark & Fujimoto 1991)
1	Sequential approach	
2	High bandwidth technology transfer	
3	Overlapping activities with fragmented release	
4	Overlapping activities with mutual adjustments	
5	Overlapping activities with early downstream involvement	
Categories of standardization		(Morgan & Liker 2006)
1	Design standardization	
2	Process standardization	
3	Engineering skill-set standardization	

Knowledge processes

The literature study in Chapter 2 highlighted two types of boundaries regarding knowledge processes in cross-functional work practices. First, managing knowledge boundaries spanning the degree of novelty (Carlile 2004). Second, sharing knowledge across organizational boundaries (Vroom & Olieman 2011). Furthermore, Chapter 3 provided definitions on concepts and frameworks for knowledge processes.

Carlile (2004) suggest three types of knowledge boundaries: syntactic transfer of knowledge, semantic translation of knowledge and pragmatic transformation of knowledge. The syntactic transfer of knowledge describes relationships between a sender and a receiver of information and relates to sharing knowledge across-organizational boundaries e.g. in IT-systems as suggested by Vroom and Olieman (2011) or model of the product (Carlile 2004). Sharing knowledge within a known domain depends on a shared language (Carlile 2002b). When increasing novelty across the semantic boundary, language becomes inadequate thus requiring methods for translating knowledge across organizational boundaries (Carlile 2002; Carlile 2004). Even explicating tacit knowledge can be insufficient at the semantic boundary where organizational members develop shared meanings (Carlile 2002b; Carlile 2004). Instead Carlile (2002) found that standardized forms and methods could be helpful and support learning. Further enhancing novelty spanning a pragmatic boundary require negotiations creating common interests (Carlile 2004). It is a level where old knowledge is transformed and new knowledge created (Carlile 2002b). Carlile (2002) suggest that objects, models and maps are helpful when organizational members alter their known knowledge into new knowledge.

Adler (1995) suggest that increasing novelty require that organizational member use more interactive coordinating mechanisms across functions in product realization. Coordination then regards product and process fit for issues of such as manufacturability in product realization (Adler 1995). Five categories of coordination illustrate the degree of interactive coordination: non-coordination (Throw-over-the-wall), standards, schedules and plans, mutual adjustments and teams. The picture of throwing product development over the wall to production development not to mention further down the chain to production is well known (Lu & Botha 2006). Production then stands as one of the last bastions before delivering a new product to the customer that they are required to do with high quality, in time and low cost, all of which requires stable processes. However, it is not clear whether teams are sufficient when novel technology offers new opportunities for both product as well as process development and change constraints in both domains simultaneously.

Organizations can code/store explicated into IT-systems as suggested by Vroom & Olieman (2011). However, those who benefit from stored knowledge (e.g. designers in the next project and employees in assembly) is not the one that invests in storing the knowledge (designers in a completed project). Designers hesitantly spends time correcting blueprints unless they can see that the investment of time and priority ease their forthcoming design work. Designers investing time on coding knowledge from a finished project also holds them from investing the time in the next project.

One issue then regards feedback and lessons learned from previous development projects (Fundin & Elg 2010). Fundin & Elg (2010) identified five different actions to dissatisfaction feedback from customers to product design: reactive, preventive, developmental, future preventive and future developmental. The first three actions are exploitative in behaviour and the last two actions are explorative in behaviour. Even though dessatisfaction feedback from customers can lead to preventive actions in product design, there is a need for an andon[8] in the product realization process that stops the process in realtime and shorten feedback loops.

Boundary objects, coordinating mechanisms and actions to feedback as shown in table 76 aids knowledge sharing across boundaries of novelty and organizational units.

[8] Andon (Japanese: アンドン or あんどん or 行灯) is a manufacturing term referring to a system to notify management, maintenance, and other workers of a quality or process problem https://en.wikipedia.org/wiki/Andon_(manufacturing).

76. Elements and dimensions describing knowledge processes for cross-functional work practices in product realization		
		References
Boundary objects for spanning knowledge boundaries		(Carlile 2002b; Carlile 2004)
1	Repositories such as IT-systems (syntactic)	
2	Standardized forms and methods(semantic)	
3	Objects, models and maps (pragmatic)	
Coordinating mechanisms		(Adler 1995)
1	Non-coordination	
2	Standards	
3	Schedules and plans	
4	Mutual adjustments	
5	Teams	
Actions to dissatisfaction feedback		(Fundin & Elg 2010)
1	Reactive	
2	Preventive	
3	Developmental	
4	Future preventive	
5	Future developmental	

Horizontal and vertical collaboration

Cross-functional work practices in product realization depends on multidisciplinary collaboration in a climate with ambiguous or conflicting goals (Lu & Botha 2006; Valle & Vázquez-Bustelo 2009). The collaboration between organizational members adds a relational element to the characteristics of work practices in product realization. Horizontal collaboration follows the workflow in product realization processes from product design to production. The vertical coordination authorize organizational members' actions toward strategic objectives and goals. Coordinating activities horizontally and vertically in product realization processes then imply developing a shared understanding of what to do, why and with what priority. Are the organizational members in product realization supposed to coexist with tension and learn to reconcile ambiguous or conflicting goals or are they to seek alignment in a negotiating process? Then Kahn (2005) suggest that even status among departments promote product development performance.

Backström et al. (2017) presents a framework for comprising four interrelated processes. In the center of the framework, new products links production processes (producing and distributing products) to innovation processes (creating and implementing new products) (Backström et al. 2017). Both production processes and innovation processes contribute to the value creation process that comprise costumer value based on developed and delivered product (Backström et al. 2017). The knowledge process embedded in production and innovation processes comprise emergence and distribution of knowledge. Backström et al. (2017) exemplify four dichotomies related to these four interrelated processes: stability and change relates to production processes, control and creativity to innovation processes, exploitation and exploration to knowledge creation processes, and efficiency and effectiveness to value creation processes.

These dichotomies are in line with literature on organizational ambidexterity where organizations trade off exploitative and explorative learning behavior (March 1991; Rodan 2005) by separation in the organizational structure (Tushman & O'Reilly III 1996), rhythmic sequencing (Benner & Tushman 2003) or contextual reconcile in management behavior (Gibson & Birkinshaw 2004). Tushman and O'Reilly III (1996) relates exploitation to incremental change and exploration to radical change. Literature within organizational ambidexterity discuss spanning organizational as well as knowledge boundaries (Katila & Ahuja 2002) and address the productivity dilemma (Benner & Tushman 2003; Adler et al. 2009; Benner & Tushman 2015).

Backström (2017) suggest that there are four ways organizations can handle dichotomies. First by suppression of one dichotomy within one system. However, literature agree that organizations needs both exploitation and exploration thus needs to be ambidextrous (March 1991; Tushman & O'Reilly III 1996; Gibson & Birkinshaw 2004; Birkinshaw & Gupta 2013). Secondly, sequential separation of dichotomies organizationally in independent subsystems corresponds with Adler's (1995) coordination mechanisms between functions. Thirdly, Parallel sub-processes within separate sub-system leads to temporal separation of time spent on the dichotomies (Backström 2017). Temporal separation can for example be that organizational members carry out problem-solving activities separate from operational work processes. Fourthly, emergent with two interconnected sub-processes within one system and relates to contextual ambidexterity (Gibson & Birkinshaw 2004; Backström 2017).

Table 77 summarize the elements and dimensions describing horizontal and vertical collaboration in cross-functional work practices.

77. Elements and dimensions describing horizontal and vertical collaboration in cross-functional work practices in product realization

		References
Processes related to dichotomies		(Backström et al. 2017)
1	Explicit production processes of stability and change	
2	Explicit innovation processes of control and creativity	
3	Embedded knowledge creation processes of exploitation and exploration	
4	Embedded value creation processes of efficiency and effectiveness	
Handling dichotomies		(Backström 2017)
1	Suppression of one dichotomy within one system	
2	Sequential separation of dichotomies organizationally in independent subsystems	
3	Parallel sub-processes within separate sub-system	
4	Emergent with two interconnected sub-processes within one system	

Workflow and structures, knowledge processes as well as horizontal and vertical collaborations forms three dimensions in a contingency framework describing the characteristics of cross-functional work practices in product realization.

12.3 Discussion on challenge in cross-functional work practices in product realization

In the following section, I discuss the findings of RQ2: “What challenge cross-functional work practices in product realization in a medium sized Engineer-To-Order respectively a large Make-To-Stock manufacturing enterprise?” I presented the preliminary findings in case A1 and B1 in Chapter 8. These preliminary findings scoped the application of the CII-program described in Chapter 9. The preliminary findings show that the two cases may very well be different in size and type of product realization processes. However, they represent their models of workflow as sequential even though they are overlapping in practice. The challenges in case A1 relates to sharing knowledge and resources across functions and case B1 the challenges relates to sharing knowledge and resources across projects. The intentions and incentives for coordinating developing activities that improves product realization processes then needs to span these organizational boundaries accordingly. I presented an analysis of the sources to these challenges in chapter 10. The cross-case analysis showed that the relationships between stakeholders in case A1 appears to be abstract, distant and with a focus on structured processes where the relationships between stakeholders in case B1 are specific, close and appear ac personalized collaboration. Contradicting objectives appear in both cases, where case A1 represent stabilization versus new product and process introductions and case B1 represent standardization versus customization. These sources leads to lack of alignment in both cases where coordination is an issue in case A1 and workarounds is an issue in case B1.

Characterizing the challenges in case A1 and B1 by emphasizing workflow and structure, knowledge processes and coordination show that workflows in both cases are described as linear processes and that there is a need for aligning intention and incentives. What differentiates case A1 and B1 is that challenges in case A1 is characterized by a need to span functional boundaries, where case B1 show a need for spanning project boundaries. Company A has large repositories of knowledge in IT-systems, however one could question whether they are part of daily workflows and thus updated.

Interestingly, companies such as company A and company B still apply sequential models for their workflows even though they work in parallel with overlapping activities. There could be various reasons for such decisions. However, I would exclude the reason that the companies are unaware of the opportunities in more concurrent and integrated models for product realization processes. Then what is the challenges that restrain progressing to more integrative models for workflows?

Company A has product managers that have access to designers and engineers within specialized functions. Data in case A1 is, however, insufficient to describe the “weight” of the product manager. The model for product realization is visualized as sequential with overlapping activities. Standardization is a prevailing method to coordinate and negotiate workflows in product realization processes. This emphasis on routinization restrain considering the actual need for standards, types of standards and degree of standardization.

Company B apply a team-based coordination mechanism and mode of integration with a project manager leading a designated team from order to sign-off at the customer. Project managers at company B has developed a project model in a collective process that crates shared meanings and generates collective thinking and action. A project model is a meta-level standardization that can contain coded learnings from experience or embedded knowledge. Considering different types of standardizations (product, work process or model) and degree of standardization could support the internal dialog about increasing standardization without restraining the company’s flexibility to customize products. Findings from case B2 also show that designers are foot-dragging toward spending time in assembly correcting blueprints unless they can see that the investment of time and priority ease their forthcoming design work. As such, designers lack incentives for investing in frontloading knowledge to increase workflow integration.

12.4 Discussion on activities facilitate organizational learning processes

The third sub-question in this research regarded activities that facilitate organizational learning processes. I founded the answer on the 4I framework proposed by (Crossan et al. 1999) and case studies applying the framework (Zietsma et al. 2002; Crossan & Berdrow 2003; Berson et al. 2006; Schulze et al. 2013). I identified activities that facilitate the four I’s Intuiting/attending, Interpreting/experimenting, Integrating and Institutionalizing and found support for the activities in case study A4, A5 and B4. In these case studies, testing the CII-program provided learning opportunities for participants as well as generated data for studying facilitating activities. Table 78 show the facilitating activities identified in the case studies.

78. Activities facilitating organizational learning processes in case study A4, C5 and B4				
Facilitating activities	***I Intuiting/attending II Interpreting/experimenting III Integrating IIII Institutionalizing***	***Case A4***	***Case A5***	***Case B4***
Communicate	I	X	X	X
Challenging cognitive maps	I – II	X	X	X
Reflection	I – II	X	X	X
Inquiry	II	X	X	X
Storytelling	II	0	0	0
Dialog	II – III	X	X	X
Visualization	II – III	X	X	X
Shared Meaning	III	X	X	X
Collective thinking	II – III - IIII	X	X	X
Collective action	IIII	X	0	X

The integration of new organizational practices in product realization was then in focus for the following sub-question.

12.5 Discussion on activities that facilitate integration of new organizational practices

Findings from seven case studies of applying prototypes and testing the CII-program show that dialog, visualizations, shared meaning and collective thinking facilitated integration of new work practices into product realization.

In the case studies A2 – A5, exemplified that integration can be restrained even though participants have a respectful dialog about the problems, visualize their insights; develop a shared meaning and collective thinking of possible solutions to the problems. An observation in case A5 show that participants continuing dialog were unable to provide multiple suggestion for solutions to the problems they were trying to solve. They were unable to break into double loop learning (Argyris & Schon 1996). The vicious circle of more dialog led to more describing experience as not no facts of data, no observation and no experimentation took place. This behavior could indicate a double bind situation (Bateson 2000) where further negotiation in the group of management representatives was needed. The situation questions what holds data back when there is an abundancy of it. In case A3 and A4 at the factory had similarly an abundancy of data, however they were unable to provide data that was relevant for the actual problem solving work.

In case B2 – B4, findings from the development process show that practitioners gain increased insight into cross-functional Engineer-To-Order processes and the improvement process.

The fact that the design criteria, activities, and tools used in the CII-program are changed based on applications of prototypes does not itself confirm that prototyping is useful when developing a CII-program. However, in this case the following findings were gained from applying prototypes of the CII-program:

- Scoping application of the CII-program is a tool for engaging management in continuous improvement and innovation of Engineer-To-Order processes.
- Using storyboards helps participants and the facilitator focus on the task instead of each other.
- Participants on all levels and across functions gained insight into their Engineer-To-Order processes.
- Participants on all levels and across functions also gained insight into each other's work, challenges, and interdependencies.
- The program designer (the author in this case) gained valuable feedback regarding gaining momentum in the program.
- The program designer gained valuable insights into practitioners' difficulties in developing their processes as part of their daily development work.

Furthermore, it became evident that participants and facilitators (in this case the author) constantly had to work on both a product level and a process level. The participants focused on both the equipment they were designing and the Engineer-To-Order -processes. The facilitator focused on the CII-program as a product supporting practitioners' development of their Engineer-To-Order processes. In addition, the facilitator focused on the program development process. These observations are relevant to compare with classifications of learning levels made by Gregory Bateson (Bateson 2000). According to Bateson (2000), "learning" implies a change that can be progressive or regressive in nature. Second-order learning is the ability of learning to learn, which means that the learning achieved in a context can be transferred to another context to become increasingly better at solving problems (Bateson 2000). Learning to learn in a new context entails a use of this habit and requires the creation of a new habit and possibly breaking the existing habit (Bateson 2000).

12.6 Discussion on the CII-program

The CII-program provides an answer for the main research question: how can manufacturers integrate new organizational practices into product realization. The combination of design thinking and lean thinking provides a creative problem-solving process with a rhythmic shift between divergent and convergent thinking. The findings from application of the program show that participants can develop a shared understanding of multiple courses to the problems and create multiple suggestions for solutions. The most significant finding from applying the program is however scoping process with management representatives.

This study propose that scoping a task together with management representatives prior to cross-functional problem solving supports horizontal and vertical coordination. In the horizontal dimension, the scoping step facilitates management representatives negotiating of a task, clarifying the present situation and setting targets for a future scenario. The scoping step also facilitate that management representatives clarify relevance and importance of the task according to the company's strategy and customers. Management representatives then asses what stakeholders are relevant for solving the task, appoint a group for solving the task and negotiate what is in scope and out of scope. The scoping step thus facilitated alignment of expectations among the management representatives. In the vertical dimension, the scoping step facilitated the hand-over of a specific task from management representatives to a cross-functional group with the scoping storyboard as a boundary object. The scoping storyboard provided the assigned group with a visualization of what the management representatives had agreed. The scoping storyboard supported the group to stay on track while working on the task. This was especially helpful when the group was stuck in discussions and tried to establish a sense on common purpose. In addition, that management representatives had scoped the task provided the group with authorization to act. As such, the scoping align the groups work with the management representatives' intentions for the work.

Storyboards for the scoping and problem-solving activities played a vital role in case A4, A5, B3 and B4. Participants in the chronicle workshops mentioned the storyboards as helping them being on track when the dialog drifted to explore various experiences. The storyboard from management representatives scoping the task also assured participants in the following activities of the importance and legitimacy in solving the specific task to which they were assigned. In this way, the storyboards functioned as boundary object and supported the participants spanning organizational boundaries as described by Carlile (2002; 2004).

13 Conclusions

This chapter concludes my dissertation by first summarize my theoretical contributions placed in the intersection of operation management, knowledge management and organizational learning. Secondly, I summarize my practical contribution of a CII-program. Thirdly, I suggest implications for practice in future use of the CII-program. Fourthly, I point out limitations in this research of which scholars needs be aware. Finally. I propose three themes in an agenda for future research on organizational learning processes of the CII-program, product realization systems and stakeholder relationships within collaborative research methods.

The initial purpose of this research was:

- to develop and test a CII-program that integrates cross-functional work practices into product realization,
- to enhance understanding of organizational learning processes in cross-functional and multilevel settings within manufacturing.

The main research question for this research was:
"How can manufacturers integrate new organizational practices into product realization processes?"

Answering this research question is supported by the following sub-questions:

RQ1: What characterizes cross-functional work practices in product realization?

RQ2: What challenge cross-functional work practices in product realization in a medium sized Engineer-To-Order respectively a large Make-To-Stock manufacturing enterprise?

RQ3: What activities facilitate organizational learning processes in improving product realization?

RQ4: What activities facilitate integrating new organizational practices in product realization?

The first two sub-questions concern the context of product realization processes and provide an understanding of the problems the companies are trying to solve. The following two sub-questions provide an understanding of organizational learning processes when disentangling these challenges and integrating solutions into product realization processes.

13.1 Theoretical contribution

The two sub-questions RQ1 and RQ3 provide theoretical contributions from this research. Furthermore, this research contribute to theoretical discussions about collaborative methods for researchers and practitioners.

Characterizing cross-functional work practices in product realization

Cross-functional work practices in product realization is characterized by challenges in workflow and structures, knowledge processes as well as horizontal and vertical collaboration. A literature study show that workflow and structures are characterized by integration and involvement across parallel workflows. Systemizing, modularity and standardizing is the prevailing approach to address challenges in cross-functional workflows and structures. Literature within operation management propose adjusting workflows and structures according to modes of integration and structures for integration in workflows. In addition, literature propose adjusting workflows and structures in product realization according to the level of routinization, task characteristics and categories of standardization.

The literature study also show that explicated knowledge is shared in formal systems and tacit knowledge is shared in teams and by involvement. Literature within knowledge management propose applying boundary objects for spanning knowledge boundaries such as developing repositories that support transferring knowledge across functions, standardized forms and methods that support translating knowledge across functions as well as objects, models and maps that support transforming knowledge across functions. Literature within operation management propose five levels of coordinating mechanism: non-coordination, standards, schedules and plans, mutual adjustments and teams.

Finally, the literature study show that horizontal and vertical collaboration concern aligning objectives, organizing and nurturing specialized expertise as well as management's role in providing incentives for collaboration. For horizontal and vertical collaboration across functions in product realization, literature within operation management propose that processes are related to dichotomies such as explicit production processes of stability and change, explicit innovation processes of control and creativity, embedded knowledge creation processes of exploitation and exploration as well as embedded value creation processes of efficiency and effectiveness. Organizations handle these dichotomies by suppressing one dichotomy within one system, sequential separating dichotomies organizationally in independent sub-systems, parallel sub-processes within separate sub-systems or as emergent with two interconnected sub-systems within one system.

Matching these findings in literature with empirical findings show that challenges in the two case studies of a large make-to-order manufacturing enterprise (company A) and a medium-sized engineer-to-order manufacturing enterprise (company B) relates to inadequacies in workflows and structures, knowledge processes as well as horizontal and vertical collaboration. Both company A and company B struggled in creating integrational workflows across functions in product realization though phasing the challenges as relating to insufficient knowledge sharing. However, sources to insufficient knowledge sharing also rooted in workflows and structures insufficiently supporting horizontal and vertical collaboration.

Relations to stakeholders in case A1 exemplify that deep specialization in functional structures encourage structured processes, high level negotiation of authority to act, and top down priorities for development actions. Subsequent application of the CII-program focused on horizontal collaboration and knowledge processes in order to compensate for lacking cross-functional collaboration. While testing the CII-program in case A4 and A5, the Scoping process facilitated aligning ambiguous or conflicting goals among management representatives and authorize the participants to act.

The personalized relations between stakeholders in case B1 encouraged individual bottom up initiatives for development actions and restrained explicating knowledge processes. The bottom up processes however was not necessarily authorized from the top leading to a situation where some organizational members was reluctant to invest resources in development actions. The management team chose knowledge sharing problems as focus for application of the CII-program in case B2, B3 and B4 in order to improve efficiency in the projects. Negotiating the scope for case B2 and B3 as well as applying the Scoping activity with the management team in company B facilitated alignment of ambiguous or conflicting goals and authorized the participants to act.

However, literature spanning the entire product realization process and include product development, production development and production is almost absent. Cross-functional issues mostly refer to spanning multidisciplinary functions within development functions. Case study A1 and B1 primarily had a general perspective on challenges in the companies. My aim for these case studies was to clarify application areas for prototyping a CII-program. Future research can then benefit from further studies of the relationship between workflows and structures, knowledge processes, as well as horizontal and vertical collaboration. These findings herewith enhance our understanding of cross-functional work practices in product realization in two types of manufacturing enterprises, a large make-to-stock and a medium-sized engineer-to-order.

Activities facilitating organizational learning processes in improving product realization

Another theoretical contribution from this research is proposed activities that facilitate organizational learning processes related to the 4I framework of Intuiting, Interpreting, Integrating and Institutionalizing in a CII-program. This study propose that communicating facilitate intuiting or attending learning processes. Challenging cognitive maps and reflection facilitate both intuiting or attending, and interpreting or experimenting learning processes. Organizational members inquiring into scoped problems facilitate interpreting or experimenting learning processes. Dialog and visualization facilitate both interpreting or experimenting and integrating learning processes. Shared meaning facilitated integration and collective action facilitated institutionalizing organizational learning processes. Finally facilitate collective thinking interpreting or experimenting, integrating and institutionalizing learning processes.

I first identified the activities facilitating organizational learning processes in case studies applying the 4I framework and then analyzed in the application of the CII-program. Application of the CII-program primarily focused on the group level with organizational members from different functions thus target integrating learning processes though organizational members contribute with their individual intuitions, attend to ambiguous or conflicting goals and takes part of interpreting and experimenting processes. The scoping activities in the CII-program relates the groups work to the organizational level and the institutionalizing learning process. The CII-program thus span individual, group and organizational level.

Findings from analyzing the application of the CII-program show that experimentation through observations and fact-finding are critical for a group of organizational members to take collective action and institutionalize suggested solutions. Findings also indicate that a multiplicity of action challenge organizational members cognitive maps and provide a futile ground for collective thinking and action.

The ground for proposing activities that facilitate organizational learning processes include case studied in literature that apply the 4I framework as well as my own case studies. The facilitating activities are not excusive. Further research can expand the list of activities and verify the relationship between organizational learning processes in the 4I framework and facilitating activities. In addition, other frameworks for organizational learning processes can bring other perspective on the issue. This study enhance our understanding of organizational learning processes in change programs such as a CII-program by proposing activities that facilitate organizational learning processes related to the 4I framework.

Collaborative methods for researchers and practitioners

This study show how researchers can design a CII-program in a collaborative probe-and-learn process as an alternative to base program design on theory before testing it in practice. This study provide rich case descriptions of the challenges in two manufacturing enterprises as well as a probe-and-learn process of designing and application a CII-program. The case study of the challenges in the two companies ensured applicability of the program. The case study of prototyping and testing the CII-program further ensured applicability of the CII-program in practice.

A probe-and-learn process imply that a researcher apply an unfinished program such as the CII-program in this case. Early feedback of from applying prototypes of the program thus contributed to further refinements of the CII-program. Applying a probe-and-learn process imply close collaboration with practitioners on challenges they experience in their daily work. Research activities can evoke oppressed tensions for organizational members in the participating companies. Thus, entangle a researcher into ambiguous and conflicting agenda's between organizational members in the company or between organizations in a consortium.

Thus, a probe-and-learn process is possible and beneficial for designing a CII-program. However, based on my personal experience from this research project I advise other researchers to address potentially conflicting issues in early scoping of a research project.

13.2 Practical contribution

The two sub-questions RQ2, RQ3 and the overall research question provide practitioners with guidance in identifying and solving challenges in cross-functional work practices in product realization.

Challenging cross-functional work practices in product realization

This research contribute with two case descriptions of cross-functional challenges in product realization processes that can serve as an inspiration for other manufacturing enterprises. Case study A1 and B1 illustrate that organizational structure and the approach to standardizing work processes influence the degree of formalization in knowledge processes. Subsequently, collaboration across functions depends on the organizations ability to handle ambiguous or conflicting goals. The absence of organizational structures that support cause counterproductive tensions between conflicting agenda.

These findings suggest that management representatives address these considerations when faced with challenges in product realization processes. One option is to appoint key performance indicators that span across organizational functions and link it to the product realization process. One such key performance indicator could be lead-time for product realization creating a common incentive for collaboration. Another option is to integrate practices for sharing both explicit and tacit knowledge in the workflow enabling coordination across functions within projects as well as across projects.

Case studies for this research include two manufacturing enterprises thus illustrating challenges in a large make-to-stock and a medium-sized engineer-to-order company. An alternative explanation to the challenges in to cases could relate to the companies' respective development stage. Nevertheless, manufacturing enterprises could be able to recognize the challenges described in case study A1 and B1.

CII-program for integrating new organizational practices into product realization

This study propose how manufacturing enterprises can continuously improve and innovate product realization processes by applying a CII-program. The CII-program distinguish from other similar programs by combining design thinking and lean thinking in a creative problems solving approach that imply rhythmic shifts between divergent and convergent thinking. The CII-program include a scoping activity that enable management representatives provide cross-functional problem solving activities with clear ground an directions for handling ambiguous or conflicting goals. The CII-program thus combine a top-down approach with bottom-up involvement of organizational members across functions. Furthermore, the CII-program apply a product realization processes perspective on horizontal integrating processes spanning two systems (product development and production) with two types of logic (development and operation).

In case A2 and A3, I observed cross-functional meetings and improvement activities in an electronics factory. In case B2 and B3, I applied the program twice with participants from Engineering and Assembly functions. Evaluation of the prototype of the program adjusted the program according to predefined design criteria. In addition, the evaluation adjusted the design criteria to be more precise.

This study completed tests of the program in both companies for case A4, A5 and B4. The test in case A4 focus on establishing an Analysis function across mutual products in an electronics factory. The test in case A5 focus on a specific product and process development of a lid to a pump-controller across product development, tool development, and production functions. The test in case B4 focus on improving the handling of deviations in a specific engineer-to-order process with participation from production, engineering, logistics, and quality functions. By applying the program, participants gained insight and shared understanding of problems in cross-functional work practices, proposed and evaluated countermeasures, and subsequently implement selected countermeasures. I evaluate the test of the programs together with the participant in chronicle workshops.

This research contribute with in-depth case descriptions of activities that facilitate integrating new organizational practices into product realization processes. The cases thus provide illustrative examples that manufacturing enterprises can recognize and utilize in their future work for continuously improving and innovating product realization processes.

13.3 Implications for practice

This project contributes an in-depth description of applying prototypes in a probe-and-learn process of developing a CII-program. The CII-program offers manufacturing enterprises an alternative to adapting existing concurrent engineering, integrated product development or lean product development proposed ways of working with product realization. The CII-program builds on organizational development principles thus combining top-down with bottom-up approach in creating answers to manufacturing enterprises challenges in cross-functional work practices in product realization. Test of the program show the following implications for organizational members:

- A program cannot change management's (or others) willingness to change, however, increased focus on the consequences of inefficient processes could be a first step.
- Using the program comprise its own learning process for participants and researchers to understand and consistently apply all elements of the program.
- Resources for improvement activities as part of daily operations depend on management priorities even though the program is applied for problems emphasized by management.

I share my findings with others (such as Force) so that they can apply the program without my participation. This part of the study contributes with further refinements of the continuous improvement and innovation program as well as clarifying how to overcome implications in using the program.

13.4 Limitations

To this point, I have only applied the CII-program in three cases in two companies. Therefore, more applications can contribute to further refinement of the activities and additional tools. Especially applications with mutual other facilitators can eliminate the bias m participation add to research and subsequently influence the findings.

Is lack of knowledge sharing the root cause of problems in product and process development? Focusing on this question as part of applying the CII-program could initiate inquiries into alternatives to improving knowledge sharing such as applying modularization, frontloading or set-based concurrent engineering. These alternative solutions has not been considered for improving process and change the logic of work practices in product and process development.

13.5 Agenda for future research

I would like to finalize this dissertation by proposing an agenda for future research within two overall themes. First, future research could contribute to the understanding of organizational learning processes in a CII-program. Secondly, further research could contribute to the understanding of product realization systems. Thirdly, further research could contribute to understanding challenges in collaboration between researchers and practitioners.

Following questions could contribute to further understanding of organizational learning processes in a CII-program:

- What activities facilitate Institutionalizing new practices in product realization? E.g. what activities in the evaluation part of the program could facilitate organizational learning processes?
- How can practitioners evaluate the outcome of applying the CII-program?
- How can storytelling facilitate organizational learning processes in a CII-program?
- Can reframing product and process development as a value stream creating value for customers (What is value and what is waste) be applied in a CII-program?
- What hinder and promote organizational learning processes in a CII-program? E.g., what influence does homogeneity and heterogeneity in the group that apply the CII-program have on the organizational learning process and the outcome of the activities?
- How could the CII-program span inter-firm collaboration with external stakeholders such suppliers or customers?

- How can practitioners take a contingency approach in applying the CII-program?

Following questions could contribute to further understanding of product realization systems:

- What constitute a product realization system? What is the systems boundaries, sub-systems and elements?
- What is the relationship between workflows and structures, knowledge processes, as well as horizontal and vertical collaboration in product realization systems?
- What characterize cross-functional challenges spanning multidisciplinary functions across production and development functions in different size and types of manufacturing enterprises e.g. entrepreneurial SME's or large multinationals and mass-customization?
- What integrating roles has practice developed for product realization systems? E.g., what role does a Chief Engineer have at Toyota?
- How does pushing the boundaries of novelty and new technological opportunities influence cross-functional collaboration between product development, production development and production?
- What are the organizational capabilities to renew own work processes in production functions and development functions?
- How can manufacturing enterprises enable informal networking opportunities for sharing tacit knowledge across functions in product realization?

Following questions could contribute to understanding challenges in collaboration between researchers and practitioners:

- What characterize the paradoxical practices in the relationship between an internal specialist (lean manager) and the researcher as facilitator regarding the participatory process?
- What characterize the challenges in applying an abductive approach in collaborative research? How can a researcher manage ambiguous objectives from stakeholder's expectations to in short-term delivery and long-term research findings?
- Is the program applicable for other settings than product and process development in manufacturing enterprises?
- How can a researcher scope a research project together with practitioners and maintain a supportive collaborative climate throughout completing research?

Referencer

Abernathy, W.J., 1978. Patterns of Industrial Innovation. *Technology Review*, 80(7).

Adler, P.S., 1995. Interdepartmental Interdependence and Coordination: The Case of the Design/Manufacturing Interface. *Organization Science*, 6(2), pp.147–167..

Adler, P.S. et al., 2009. Perspectives on the productivity dilemma. *Journal of Operations Management*, 27(2009), pp.99–113..

Adler, P.S., Goldoftas, B. & Levine, D.I., 1999. Flexibility Versus Efficiency? A Case Study of Model Changeovers in the Toyota Production System. *Organization Science*, 10(1), pp.43–68..

Akgun, A.E., Lynn, G.S. & Byrne, J.C., 2006. Antecedents and Consequences of Unlearning in New Product Development Teams. *Journal of Product Innovation Management*, 23(1), pp.73–88.

Almahendra, R. & Ambos, B., 2015. Exploration and exploitation: a 20-year review of evolution and reconceptualisation. *International Journal of Innovation Management*, 19(1).

Alvesson, M., 2003. Beyond Neopositivists, Romantics, and Localists: A Reflexive Approach to Interviews in Organizational Research. *The Academy of Management Review*, 28(1), p.13.

Anand, J., Mulotte, L. & Ren, C.R., 2016. Does experience imply learning? *Strategic Management Journal*, 37(7), pp.1395–1412.

Anderson, P., 1999. Complexity theory and organization science. *Organization Science*, 10(3).

Angelis, J. & Fernandes, B., 2012. Innovative lean: work practices and product and process improvements. *International Journal of Lean Six Sigma*, 3(1), pp.74–84.

Argote, L., 2013. *Organizational Learning*, Boston, MA: Springer US.

Argyris, C., 1996. Crossroads—Unrecognized Defenses of Scholars: Impact on Theory and Research. *Organization Science*, 7(1).

Argyris, C., 2008. Teaching Smart People How to Learn. *Harvard Business School Press Books*.

Argyris, C., 2003. A Life Full of Learning. *Organization Studies*, 24(7), pp.1178–1192.

Argyris, C. & Schon, D., 1978. *Organizational Learning: A Theory of Action Perspective*, Reading MA: Addison-Wesley Publishing Company, Inc.

Argyris, C. & Schon, D., 1996. *Organizational learning II. Theory, method and practice*, Addison-Wesley Publishing Company,.

Backström, T., 2017. Solving the Quality Dilemma: Emergent Quality Management. In *Innovative Quality Improvements in Operations*. pp. 151–166.

Backström, T., Fundin, A. & Johansson, P.E., 2017. *Innovative quality*

improvements in operations : introducing emergent quality management, Springer International Publishing.
Barney, J., 1991. Firm Resources and Sustained competitive advantage. *Journal of Management*, 17(1), pp.99–120.
Bartlett, C.A., 1994. Changing the Role of Top Management: Beyond Strategy to Purpose. *Harvard Business Review*, 72(6).
Bartlett, C.A., 1995. Changing the Role of Top Management: Beyond Systems to People. *Harvard Business Review*, 73(3).
Bateson, G., 2000. The Logical Categories of Learning and Communication. *Steps to an Ecology of Mind*, p.279~308.
Beckman, S.L.S. & Barry, M., 2007. Innovation as a Learning Process: embedding design thinking. *California Management Review*, 50(1), pp.25–56.
Bellgran, M. & Säfsten, K., 2010. *Production Development*, London: Springer London.
Benner, M. & Tushman, M., 2002. Process management and technological innovation: A longitudinal study of the photography and paint industries. *Administrative Science Quarterly*, 47(4), pp.676–706.
Benner, M.J. & Tushman, M.L., 2003. Exploitation, Exploration, and Process Management: The Productivity Dilemma Revisited. *The Academy of Management Review*, 28(2), p.238.
Benner, M.J. & Tushman, M.L., 2015. Reflections on the 2013 Decade Award--"Exploitation, Exploration, and Process Management: The Productivity Dilemma Revisited" Ten Years Later. *Academy of Management Review*, 40(4), pp.497–514.
Berson, Y. et al., 2006. Leadership and organizational learning: A multiple levels perspective. *The Leadership Quarterly*, 17(6), pp.577–594.
Bessant, J. & Caffyn, S., 1997. High-involvement innovation through continuous improvement. *International Journal of Technology Management*, 14(1), p.7.
Bicheno, J., Holweg, M. & Bicheno, J., 2009. *The Lean toolbox : the essential guide to Lean transformation*, PICSIE Books.
Birkinshaw, J. & Gupta, K., 2013. Clarifying the distinctive contribution of ambidexterity to the field of organization studies. *Academy of Management Perspectives*, 27(4).
Blackler, F., 1995. Knowledge, Knowledge Work and Organizations: An Overview and Interpretation. *Organization Studies*, 16(6), pp.1021–1046.
Boer, H. et al., 2001. Knowledge and continuous innovation. *International Journal of Operations & Production Management*, 21(4), pp.490–504.
Boer, H. & Gertsen, F., 2003. From continuous improvement to continuous innovation: a (retro)(per)spective. *International Journal of Technology Management*, 26(8), p.805.
Bogers, M. & Lhuillery, S., 2011. A Functional Perspective on Learning and

Innovation: Investigating the Organization of Absorptive Capacity. *Industry & Innovation*, 18(6), pp.581–610.

Bradbury, H. & Reason, P., 2003. Action Research: An Opportunity for Revitalizing Research Purpose and Practices. *Qualitative Social Work*, 2(2), pp.155–175.

Brown, T., 2015. Design for Action. *Harvard Business Review*, 93(9), pp.57–64.

Brown, T., 2008. Design thinking. *Harvard Business Review*, 86(6).

Cacciatori, E., Tamoschus, D. & Grabher, G., 2012. Knowledge transfer across projects: Codification in creative, high-tech and engineering industries. *Management Learning*, 43(3), pp.309–331.

Carayannis, E.G., 1999. Fostering synergies between information technology and managerial and organizational cognition: the role of knowledge management. *Technovation*, 19(4), pp.219–231.

Carlile, P.R., 2004. Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge across Boundaries. *Organization Science*, 15(5).

Carlile, P.R., 2002. A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science*, 13(4).

Carlile, P.R. & Rebentisch, E.S., 2003. Into the Black Box: The Knowledge Transformation Cycle. *Management Science*, 49(9).

Chirumalla, K., 2017. Lessons Learned Practice in a Complex Production Environment. In *Innovative Quality Improvements in Operations*. pp. 113–130.

Chiva, R., Grandio, A. & Alegre, J., 2010. Adaptive and Generative Learning: Implications from Complexity Theories. *International Journal of Management Reviews*, 12(2).

Chiva, R. & Habib, J., 2015. A framework for organizational learning: Zero, adaptive and generative learning. *Journal of Management and Organization*.

Chiva, R. & Alegre, J., 2005. Organizational Learning and Organizational Knowledge: Towards the Integration of Two Approaches. *Management Learning*, 36(1), pp.49–68.

CIRP, 1990. Nomenclature and Definitions for Manufacturing Systems. *CIRP Annals - Manufacturing Technology*, 39(2), pp.735–742.

Clark, K.B. & Fujimoto, T., 1991. *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry*, Boston, MA: Harvard Business School Press.

Clark, K.B. & Fujimoto, T., 1988. Shortening product development lead time−the case of the global automobile industry. *Electro/88 Conference Record*.

Coghlan, D. & Brannick, T., 2014. *Doing action research in your own organization* 4th Editio., London: Sage Publications.

Cohen, W.M. & Levinthal, D.A., 1990. Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35(1), p.128.

Cole, R., 2002. From continuous improvement to continuous innovation. *Total Quality Management*, 13(8).

Costa, V. & Monteiro, S., 2016. Key knowledge management processes for innovation: a systematic literature review. *VINE Journal of Information and Knowledge Management Systems*, 46(3), pp.386–410.

Coughlan, P. & Coghlan, D., 2002. Action research for operations management. *International Journal of Operations and Production Management*, 22(2), pp.220–240.

Crabtree, B.F. & Miller, W.L., 1999. *Doing Qualitative Research* Second Edi. C. D. Laughton et al., eds., Thousand Oaks: Sage Publications, Inc.

Creswell, J.W., 2014. *Research design: Qualitative, quantitative and mixed methods approaches*,

Crossan, M.M. & Berdrow, I., 2003. Organizational learning and strategic renewal. *Strategic Management Journal*, 24(11), pp.1087–1105.

Crossan, M.M., Lane, H.W. & White, R.E., 1999. AN ORGANIZATIONAL LEARNING FRAMEWORK: FROM INTUITION TO INSTITUTION. *Academy of Management Review*, 24(3), pp.522–537.

Crossan, M.M., Maurer, C.C. & White, R.E., 2011. Reflections on The 2009 AMR Decade Award: Do We Have A Theory of Organizational Learning? *Academy of Management Review*, 36(3), pp.446–460.

Cyert, R.M. & March, J.G., 1963. *A behavioral theory of the firm*, Prentice-Hall,.

Dekkers, R., Chang, C.M. & Kreutzfeldt, J., 2013. The interface between "product design and engineering" and manufacturing: A review of the literature and empirical evidence. *International Journal of Production Economics*, 144(1), pp.316–333.

Dixon, N.M., 1994. *The organizational Learning Cycle: How We Can Learn Collectively* Second Edi., Aldershot: Gower Publishing Limited.

Dover, P.A. & Dierk, U., 2010. The ambidextrous organization: integrating managers, entrepreneurs and leaders. *Journal of Business Strategy*, 31(5), pp.49–58.

Dubois, A. & Gadde, L.-E., 2014. "Systematic combining"—A decade later. *Journal of Business Research*, 67(6), pp.1277–1284.

Dubois, A. & Gadde, L.-E., 2002. Systematic combining: an abductive approach to case research. *Journal of Business Research*, 55(7), pp.553–560.

Dutta, D.K. & Crossan, M.M., 2005. The Nature of Entrepreneurial Opportunities: Understanding the Process Using the 4I Organizational Learning Framework. *Entrepreneurship Theory and Practice*, 29(4), pp.425–449.

Eisenhardt, K.M., 1989. Building Theories from Case Study Research.

Academy of Management Review, 14(4), pp.532–550.
Eisenhardt, K.M. & Graebner, M.E., 2007. Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, 50(1), pp.25–32.
El-Awad, Z., Gabrielsson, J. & Politis, D., 2017. Entrepreneurial learning and innovation. *International Journal of Entrepreneurial Behavior & Research*, 23(3), pp.381–405.
Ellström, P., 2015. Knowledge Creation Through Interactive Research: A Learning Perspective1.
Foss, N.J., Husted, K. & Michailova, S., 2010. Governing Knowledge Sharing in Organizations: Levels of Analysis, Governance Mechanisms, and Research Directions. *Journal of Management Studies*, 47(3), pp.455–482.
Frankenberger, K. et al., 2013. The 4I-framework of business model innovation: a structured view on process phases and challenges. *International Journal of Product Development*, 18(3/4), p.249.
Fundin, A. & Elg, M., 2010. Continuous learning using dissatisfaction feedback in new product development contexts. *International Journal of Quality & Reliability Management*, 27(8), pp.860–877.
Gadotti Martins, E., Pinheiro de Lima, E. & Gouvea da Costa, S.E., 2015. Developing a quality management system implementation process for a medical device manufacturer. *Journal of Manufacturing Technology Management*, 26(7), pp.955–979.
Galbraith, J., Downey, D. & Kates, A., 2002. Designing Dynamic Organizations: A Hands-On Guide for Leaders at All Levels. *NewYork: AMACOM*, p.5.
Ghoshal, S., 1995. Changing the Role of Top Management: Beyond Structure to Processes. *Harvard Business Review*, 73(1).
Gibson, C. & Birkinshaw, J., 2004. The antecedents, consequences, and mediating role of organizational ambidexterity. *Academy of Management Journal*, 47(2), pp.209–226.
Gourlay, S., 2006. Conceptualizing Knowledge Creation: A Critique of Nonaka's Theory. *Journal of Management Studies*, 43(7), pp.1415–1436.
Grant, R.M., 1996. Toward a knowledge-based theory of the firm. *Strategic Management Journal*, 17(S2), pp.109–122.
Grex, S. & Ipsen, C., 2010. The Chronicle Workshop - a method for to enhance and explore innovative processes in project based organisations. *International Conference on Organizational Learning, 2010*.
Groover, M.P., 2008. *Automation, production systems, and computer-integrated manufacturing*, Pearson/Prentice Hall.
Gummesson, E., 2000. *Qualitative methods in management research*, Sage.
Gupta, A.K., Smith, K.G. & Shalley, C.E., 2006. The interplay between

exploration and exploitation. *Academy of Management Journal*, 49(4), pp.693–706.
Harrington, H.J., 1991. *Business Process Improvement: the breakthrough strategy for total quality, productivity, and competitiveness*, McGraw-Hill.
Helander, M. et al., 2015. Applying lean in product development - enabler or inhibitor of creativity? *International Journal of Technology Management*, 68(1/2), p.49.
Henriksen, B. & Rolstadås, A., 2009. Knowledge and manufacturing strategy–how different manufacturing paradigms have different requirements to knowledge. Examples from the automotive industry. *International Journal of Production Research*, 48(8), pp.2413–2430.
Hill, T., 2000. *Manufacturing strategy :*, Palgrave,.
Hines, P., Holweg, M. & Rich, N., 2004. Learning to evolve: A review of contemporary lean thinking. *International Journal of Operations & Production Management*, 24(10), pp.994–1011.
Hislop, D., 2013. *Knowledge management in organizations : a critical introduction*, Oxford University Press,.
Holweg, M., 2007. The genealogy of lean production. *Journal of Operations Management*, 25(2), pp.420–437.
De Houwer, J., 2009. The propositional approach to associative learning as an alternative for association formation models. *Learning & Behavior*, 37(1), pp.1–20.
Ingvaldsen, J.A. & Rolfsen, M., 2012. Autonomous work groups and the challenge of inter-group coordination. *Human Relations*, 65(7), pp.861–881.
Jensen, A.R.V., Jensen, S.C. & Broberg, O., 2016. Participatory methods for initiating manufacturing employees' involvement in product innovation. *Proceedings of the Xxvii Ispim Innovation Conference - Blending Tomorrow's Innovation*.
Jiménez-Jiménez, D. & Sanz-Valle, R., 2011. Innovation, organizational learning, and performance. *Journal of Business Research*, 64(4), pp.408–417.
Johansson, P.E. & Osterman, C., 2017. Conceptions and operational use of value and waste in lean manufacturing – an interpretivist approach. *International Journal of Production Research*, pp.1–13.
Jones, O. & Macpherson, A., 2006. Inter-Organizational Learning and Strategic Renewal in SMEs. *Long Range Planning*, 39(2), pp.155–175.
Kahn, K.B., 2005. Department Status: An Exploratory Investigation of Direct and Indirect Effects on Product Development Performance. *Journal of Product Innovation Management*, 22(6), pp.515–526.
Karlsson, C., 2009. *Researching operations management*, Routledge.
Karlsson, C. & Ahlstrom, P., 1996. The Difficult Path to Lean Product Development. *Journal of Product Innovation Management*, 13(4),

pp.283–295.
Katila, R. & Ahuja, G., 2002. Something old, something new: A longitudial study of search behavior and new product introduction. *Academy of Management Journal*, 45(6), pp.1183–1194.
Klein, L., 1994. Sociotechnical/Organizational Design. In W. Karwowski & G. Salvendy, eds. *Organization and Management og Advanced manufacturing*. New York, New York, USA: John Wiley & Sons, Inc.
Lahteenmaki, S., Toivonen, J. & Mattila, M., 2001. Critical Aspects of Organizational Learning Research and Proposals for Its Measurement. *British Journal of Management*, 12(2), pp.113–129.
Lam, A., 2000. Tacit Knowledge, Organizational Learning and Societal Institutions: An Integrated Framework. *Organization Studies*, 21(3), pp.487–513.
Lampela, H. & Karkkainen, H., 2008. Systems thinking and learning in innovation process. *International Journal of Entrepreneurship and Innovation Management*, 8(2), p.184.
Lane, P.J., 2006. The reification of absorptive capacity: A critical review and rejuvenation of the construct. *Academy of Management Review*, 31(4).
Lavie, D., Stettner, U. & Tushman, M.L., 2010. Exploration and Exploitation Within and Across Organizations. *The Academy of Management Annals*, 4(1), pp.109–155.
Lawrence, T. et al., 2005. The politics of organizational learning: Integrating power into the 4I framework. *Academy of Management Review*, 30(1).
Lee, I.G. et al., 2013. Product orientations and the development strategies of new convergence products: moderating effects of corporate capabilities. *Asian Journal of Technology Innovation*, 21(1), pp.34–51.
Lee, J.-H. & Kim, Y.-G., 2001. A stage model of organizational knowledge management: a latent content analysis. *Expert Systems with Applications*, 20(4), pp.299–311.
Lengnick-Hall, C.A. & Inocencio-Gray, J.L., 2013. Institutionalized Organizational Learning and Strategic Renewal. *Journal of Leadership & Organizational Studies*, 20(4), pp.420–435.
Leonard-Barton, D., 1992. Core capabilities and core rigidities: A paradox in managing new product development. *Strategic Management Journal*, 13(S1), pp.111–125.
Levinthal, D.A. & March, J.G., 1993. The myopia of learning. *Strategic Management Journal*, 14.
Levitt, B. & March, J.G., 1988. Organizational Learning. *Annual Review of Sociology*, 14, pp.319–340.
Li, C.-R., 2013. Disentangling the effect of exploratory learning and exploitative learning in product innovation process. *Canadian Journal of Administrative Sciences / Revue Canadienne des Sciences de l'Administration*, 30(2), pp.101–114.
Li, Y.-H. & Huang, J.-W., 2013. Exploitative and exploratory learning in

transactive memory systems and project performance. *Information & Management*, 50(6), pp.304–313.
Liker, J.K. et al., 1996. Involving suppliers in product development in the United States and Japan: evidence for set-based concurrent engineering. *IEEE Transactions on Engineering Management*, 43(2), pp.165–178.
Liker, J.K., 2011. Lean Product Development as a System: A Case Study of Body and Stamping Development at Ford. *EMJ-ENGINEERING MANAGEMENT JOURNAL*, 23(1), pp.16–28.
Liker, J.K., 2004. *The Toyota way : 14 management principles from the world's greatest manufacturer*, McGraw-Hill.
Liker, J.K. & Convis, G.L., 2012. *The Toyota Way to Lean Leadership*, McGraw-Hill.
Liker, J.K. & Majchrzak, A., 1994. Designing the human infrastructure for technology. In W. Karwowski & G. Salvendy, eds. *Organization and Management og Advanced manufacturing*. New York, New York, USA: John Wiley & Sons, Inc.
Lin, C.-H.V. & Sanders, K., 2017. HRM and innovation: a multi-level organisational learning perspective. *Human Resource Management Journal*, 27(2), pp.300–317.
Lindlöf, L., Söderberg, B. & Persson, M., 2013. Practices supporting knowledge transfer – an analysis of lean product development. *International Journal of Computer Integrated Manufacturing*, 26(12), pp.1128–1135.
Liu, H., Luo, J. & Huang, J.X., 2011. Organizational learning, NPD and environmental uncertainty: An ambidexterity perspective. *Asian Business & Management*, 10(4), pp.529–553.
Lu, Q. & Botha, B., 2006. Process development: a theoretical framework. *International Journal of Production Research*, 44(15), pp.2977–2996.
March, J.G., 1991. Exploration and Exploitation in Organizational Learning. *Organization Science*, 2(1), pp.71–87.
Martini, A. et al., 2013. Continuous innovation: towards a paradoxical, ambidextrous combination of exploration and exploitation. *Int. J. Technology Management*, 61(1).
Maxwell, J.A., 2013. *Qualitative Research Design - An Interactive Approach* 3rd ed., Sage Publications.
Miles, M., Huberman, A.M. & Saldana, J., 2014. *Qualitative Data Analysis: A Methods Sourcebook* Third Edit., Thousand Oaks: Sage Publications, Inc.
Miltenburg, J., 2005. Manufacturing strategy how to formulate and implement a winning. *Professional Manager*, Vol. 2, p.436.
Miner, A.S. & Mezias, S.J., 1996. Ugly Duckling No More: Pasts and Futures of Organizational Learning Research. *Organization Science*, 7(1), pp.88–99.

Morgan, G., 1997. *Images of Organization*, Sage Publications.
Morgan, J.M. & Liker, J.K., 2006. *The Toyota product development system : integrating people, process, and technology*, Productivity Press.
Mulotte, L., 2014. Do Experience Effects Vary Across Governance Modes? Evidence from New Product Introduction in the Global Aircraft Industry, 1948–2000. *Organization Science*, 25(3), pp.757–775.
Nagaraj, B.V., 2004. Concurrent engineering at Titan Industries Ltd: a case study from the watch industry. *International Journal of Manufacturing Technology and Management*, 6(3/4), p.345.
Nelson, R.R. & Winter, S.G., 1982. *An Evolutionary Theory of Economic Change*, The Belknap of Harvard University Press.
Netland, T.H. & Frick, J., 2017. Trends in manufacturing strategies: A longitudinal investigation of the International Manufacturing Strategy Survey. In *International Manufacturing Strategy in a Time of Great Flux*. Springer International Publishing, pp. 1–16.
Nonaka, I. et al., 1994. Organizational knowledge creation theory: A first comprehensive test. *International Business Review*, 3(4), pp.337–351.
Nonaka, I., 1994. A Dynamic Theory of Organizational Knowledge Creation. *Organization Science*, 5(1), pp.14–37.
Nonaka, I. & von Krogh, G., 2009. Perspective—Tacit Knowledge and Knowledge Conversion: Controversy and Advancement in Organizational Knowledge Creation Theory. *Organization Science*, 20(3), pp.635–652.
O'Reilly, C.A. & Tushman, M.L., 2013. Organizational Ambidexterity: Past, Present and Future. *The Academy of Management perspectives*, 27(4).
O'ReillyIII, C.A., Harreld, J.B. & Tushman, M.L., 2009. Organizational Ambidexterity: , 51(4), pp.75–100.
O'ReillyIII, C.A. & Tushman, M.L., 2011. Organizational Ambidexterity in Action: How Managers Explore and Exploit. *California Management Review*, 53(4), pp.5–22.
Pellegrinelli, S., Murray-Webster, R. & Turner, N., 2015. Facilitating organizational ambidexterity through the complementary use of projects and programs. *International Journal of Project Management*, 33(1), pp.153–164.
Pil, F.K. & Fujimoto, T., 2007. Lean and reflective production: the dynamic nature of production models. *International Journal of Production Research*, 45(16), pp.3741–3761.
Pisano, G.P. & Wheelwright, S.C., 1995. The new logic of high-tech R&D. *Harvard Business Review*, 73(5), pp.93–105.
Pitt, M. & MacVaugh, J., 2008. Knowledge management for new product development. *Journal of Knowledge Management*, 12(4), pp.101–116.
Polanyi, M., 1983. *The tacit dimension*, Peter Smith,.
Porter, M.E. & Heppelmann, J.E., 2015. How Smart, Connected Products are Transforming Companies. *Harvard Business Review*, 93(10).

Porter, M.E. & Heppelmann, J.E., 2014. How Smart, Connected Products Are Transforming Competition. *Harvard Business Review*, 92(11).

Poulsen, S., Ipsen, C. & Gish, L., 2015. Applying the chronicle workshop as a method for evaluating participatory interventions. *International Journal of Human Factors and Ergonomics*, 3(3/4), p.271.

Raisch, S. & Birkinshaw, J., 2008. Organizational Ambidexterity: Antecedents, Outcomes, and Moderators. *Journal of Management*, 34(3), pp.375–409.

Rauniar, R. et al., 2008. Shared knowledge and product design glitches in integrated product development. *International Journal of Production Economics*, 114(2), pp.723–736.

Rauniar, R., Rawski, G. & Hudson, d., 2017. Antecedents and consequences of ippd effectiveness. *International journal of innovation management*, 21(7), p.1750059.

Richtnér, A., Åhlström, P. & Goffin, K., 2014. “Squeezing R&D”: A Study of Organizational Slack and Knowledge Creation in NPD, Using the SECI Model. *Journal of Product Innovation Management*, 31(6), pp.1268–1290.

Ries, E., 2011. *The lean startup: how today’s entrepreneurs use continuous innovation to create redically successful businesses*, Crown Business.

Rodan, S., 2005. Exploration and exploitation revisited: Extending March’s model of mutual learning. *Scandinavian Journal of Management*, 21(4), pp.407–428.

Roozenburg, N.F.M. & Eekels, J., 1995. *Product design : fundamentals and methods*, Wiley.

Sanz-Valle, R. et al., 2011. Linking organizational learning with technical innovation and organizational culture G. Martín-de Castro, ed. *Journal of Knowledge Management*, 15(6), pp.997–1015.

Saunders, M., Lewis, P. & Thornhill, A., 2012. *Research Methods for Business Students*,

Saunders, T., Gao, J. & Shah, S., 2014. A case study to evaluate lean product development practices in the global automotive industry. *International Journal of Product Development*, 19(5/6), p.307.

Schein, E.H., 2010. *Organizational culture and leadership*, Jossey-Bass.

Schein, E.H., 1999. *Process consultation revisited: Building the helping relationship*, Addison-Wesley Publishing Company, Inc.

Schmenner, R.W., 1993. *Production/operations management* Fith editi., Macmillan , Maxwell Macmillan Canada , Maxwell Macmillan International.

Schulze, A. et al., 2013. Exploring the 4I framework of organisational learning in product development: value stream mapping as a facilitator. *International Journal of Computer Integrated Manufacturing*, 26(12), pp.1136–1150.

Schönemann, M., Thiede, S. & Herrmann, C., 2014. Integrating Product

Characteristics into Extended Value Stream Modeling. *Procedia CIRP*, 17, pp.368–373.
Shingo, S., 1988. *Non-stock production : the Shingo system for continuous improvement*, Productivity Press.
Simsek, Z., 2009. Organizational Ambidexterity: Towards a Multilevel Understanding. *Journal of Management Studies*, 46(4), pp.597–624.
Stark, J., 2016. Product Lifecycle Management. In *Product Lifecycle Management (volume 2)*. pp. 1–35.
Tassoul, M. & Buijs, J., 2007. Clustering: An Essential Step from Diverging to Converging. *Creativity and Innovation Management*, 16(1), pp.16–26.
Tidd, J. & Bessant, J., 2013. *Managing innovation : integrating technological, market and organizational change* Fifth edit., Wiley.
Tomovic, M.M. & Wang, S., 2009. *Product Realization* M. Tomovic & S. Wang, eds., Boston, MA: Springer US.
Turner, N., Maylor, H. & Swart, J., 2014. Ambidexterity in projects: An intellectual capital perspective. *International Journal of Project Management*, 33(1), pp.177–188.
Turner, N., Swart, J. & Maylor, H., 2013. Mechanisms for managing ambidexterity: A review and research agenda. *International Journal of Management Reviews*, 15(3).
Tushman, M.L. & O'Reilly III, C.A., 1996. Ambidextrous organizations: Managing evolutionary and revolutionary change. *California Management Review*, (4), pp.8–30.
Tyagi, S. et al., 2015. Lean tools and methods to support efficient knowledge creation. *International Journal of Information Management*, 35(2), pp.204–214.
Ulrich, K.T. & Eppinger, S.D., 2012. *Product design and development*, McGraw-Hill/Irwin.
Utterback, J.M. & Abernathy, W.J., 1975. A dynamic model of process and product innovation. *Omega*, 3(6), pp.639–656.
Valaski, J., Malucelli, A. & Reinehr, S., 2012. Ontologies application in organizational learning: A literature review. *Expert Systems with Applications*, 39(8), pp.7555–7561.
Valle, S. & Vázquez-Bustelo, D., 2009. Concurrent engineering performance: Incremental versus radical innovation. *International Journal of Production Economics*, 119(1), pp.136–148.
Vogel, R. & Güttel, W.H., 2012. The Dynamic Capability View in Strategic Management: A Bibliometric Review. *International Journal of Management Reviews*, 15(4), p.n/a-n/a.
Voss, C.A., Tsikriktsis, N. & Frohlich, M., 2011. Case research in operations management.
Vroom, R.W. & Olieman, A.M., 2011. Sharing relevant knowledge within product development. *International Journal of Product Development*,

14(1/2/3/4), p.34.
Ward, A. & Sobek, D., 2014. *Lean Product and Process Development* 2 nd editi., Cambridge, MA, USA: Lean Enterprise Institute.
Womack, J.P., 2003. *Lean thinking : Banish waste and create wealth in Your corporation*, Free Press.
Womack, J.P., Jones, D.T. & Roos, D., 2007. *The machine that changed the world : How lean production revolutionized the global car wars*, Simon & Schuster.
Xu, J. et al., 2010. Macro process of knowledge management for continuous innovation. *Journal of Knowledge Management*, 14(4), pp.573–591.
Yamamoto, Y. & Bellgran, M., 2013. Four Types of Manufacturing Process Innovation and their Managerial Concerns. *Procedia CIRP*, 7, pp.479–484.
Yasumoto, M. & Fujimoto, T., 2005. Does cross-functional integration lead to adaptive capabilities? Lessons from 188 Japanese product development projects. *International Journal of Technology Management*, 30(3/4), p.265.
Yin, R.K., 2009. *Case Study Research: Design and Methods* L. Bickman & D. J. Rog, eds., Sage Publications.
Zietsma, C. et al., 2002. The War of the Woods: Facilitators and Impediments of Organizational Learning Processes. *British Journal of Management*, 13(S2), pp.S61–S74.
Zimmermann, A., Raisch, S. & Birkinshaw, J., 2013. The Emergent Process of Ambidexterity. *Academy of Management Proceedings*, 2013(1), pp.10160–10160.
Österlund, J. & Lovén, E., 2005. Information versus inertia: a model for product change with low inertia. *Systems Research and Behavioral Science*, 22(6), pp.547–560.

Surveys:
PwC's Global Innovation Survey 2013: Industrial manufacturing perspectives (https://www.pwc.com/gx/en/industrial-manufacturing/publications/pdf/pwc-rethinking-innovation-in-industrial-manufacturing-are-you-up-for-the-challenge.pdf)
McKinsey Global Institute 2012: Manufacturing the future (http://www.nist.gov/mep/data/upload/Manufacturing-the-Future.pdf)
BCG 2016: Winning the Industry 4.0 Race (https://innovationsfonden.dk/sites/default/files/bcg-winning-the-industry-40-race-dec-2016.pdf)

Appendix A MADE

A.1. Short introduction to Made

Structured as a collaborative organization, MADE (Manufacturing academy of Denmark) members comprise manufacturing companies, universities, and GTS-institutes (Advanced Technology Groups). Each work packages has a steering committee with a work package leader from a university, representatives from manufacturing companies, universities and GTS-institutes assigning PhD-projects to fulfil work package objectives. Work package seven comprise representatives from four manufacturing companies, a GTS-institute, and six PhD-projects at three Danish universities.

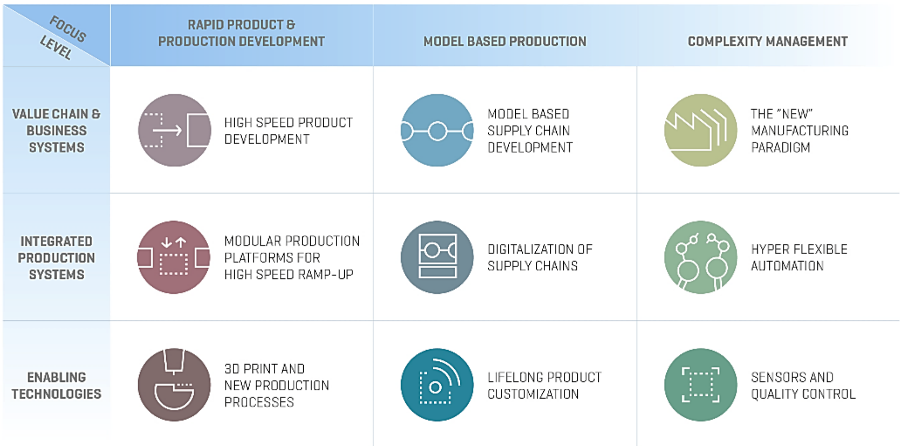

Figure 55. The nine work packages in MADE

There is more information about MADE at the website made.dk.

Appendix B Conference paper

B.1. Conference paper submitted to PIN-C 2018 conference

PROTOTYPING A CONTINUOUS IMPROVEMENT AND INNOVATION PROGRAM

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ABSTRACT

This paper investigates a development process of prototype a continuous improvement and innovation (CII) program that improves Engineer-To-Order (ETO) processes. Research for this paper comprises an in-depth description of development of a CII-program in a probe-and-learn process. The study applies action research in collaboration with a Small- and Medium-sized Enterprise (SME), applying prototypes of a CII-program on cross-functional challenges in ETO processes. Findings from the development process show that practitioners gain increased insight into cross-functional ETO-processes and the improvement process.

INTRODUCTION

Manufacturing enterprises delivering ETO solutions gain a competitive advantage from short lead-times (Willner et al. 2016) and look for ways to innovate effectively (Çakar & Ertürk 2010). Engineering lead-times include developing or adapting specifications to customer's needs within order fulfilment time (Willner et al. 2016). In practice, engineering designers set the pace for the subsequent functions, as machining cannot start before the drawings are ready. Assembly may start before all parts are finished and delivered if the received parts fit in the order of assembly, such as when having parts for the frame of the equipment or parts for a sub-assembly.

Scholars suggests that increased standardization and automation of design tasks can reduce lead-time in ETO processes (Willner et al. 2016). However, ETO manufacturers struggle in finding the appropriate degree of standardization and automation (Willner et al. 2016). Scholars claim to have solutions to this challenge by applying strategies regarding configuration of design and computer-aided-design (Willner et al. 2016). Consequently, top management in manufacturing enterprises must balance contradictory goals (S. Adler et al. 2009).

Other scholars suggest that continuous improvement of products and processes can deliver incremental innovation and increase participation (Bessant & Caffyn 1997). Boer and Gertsen (2003) define the concept of continuous innovation as "… the ongoing process of operating and improving existing, and developing and putting into use new configurations of products, market approaches, processes, technologies and competencies, organisation and management systems." However, it remains a central task for practitioners and scholars to understand which organizational practices can be adopted to balance and maintain short-term efficiency and long-term innovation capabilities (Martini et al. 2013).

Continuous improvement and innovation of products emphasize that testing prototypes in early stages of the product development process allows learning from errors through experimentation (Cole 2002). Now consider a Continuous Improvement and Innovation (CII) program for a product, and a SME the user applying a prototype of the CII-program. Similar to prototypes of products, the expectations would then be that applying prototypes of a CII-program generate insights about ETO processes for practitioners as well as learnings about the CII-program for the program designer (in this case the author). In the following, this paper seeks to understand what practitioners and researchers can learn from prototyping a CII-program in a probe-and-learn process. Even though the CII-program itself is a contribution to practitioners and scholars, it will not be discussed in this paper.

The remainder of this paper presents literature on prototyping as a probe-and-learn process and other continuous improvement and innovation programs. The second section presents the applied action research method and case description. The third section evaluates data and methods applied in this study. The fourth section then presents results of the study and include design criteria, prototypes of the CII-program and the final program. The fifth section discuss the insights practitioners gained from the study. Finally, the conclusion directs attention to further research agendas.

LITERATURE AND THEORY

PROTOTYPING

Prototyping is a familiar practice in conventional product development, as is beta testing within software development (Cole 2002). Product development applies prototypes to initiate a dialogue with production about manufacturability and marketing to customers' needs (Cole 2002). Designers prototype product concepts, engineers prototype production designs, and software developers prototype programs—all in order to gain feedback from customers or other stakeholders at an early stage of development (Ulrich & Eppinger 2012). Testing prototypes with users then becomes an iterative and learning process for both designers and users (Ulrich & Eppinger 2012).

Cole (2002) proposed a probe-and-learn process for product development that comprises probe, test, evaluate, and learn (refine) as a way of speeding up Deming's Plan, Do, Check, Act (PDCA) model. The purpose of the probe-and-learn process is to receive instant feedback from users in product development (Cole 2002). Probe-and-learn is a way of approximating the product design (Cole 2002).

CONTINUOUS IMPROVEMENT AND INNOVATION

The purpose of the CII-program is to support manufacturing enterprises that intend to enhance their ability to innovate effectively. The program builds on assumptions in organizational learning suggesting that organizations learn from experience and experimentation, from solving their own problems, and that solving these problems develop the organizational design (Argyris & Schon 1996).

There are a few examples in literature that propose combining continuous improvement and innovation in a program.

Buckler (1996) proposed an individual learning process for continuous improvement and innovation. The learning process comprises ignorance, awareness, understanding, commitment, enactment, and reflection as elements (Buckler 1996). The premise for the program is leadership's attempt to enable a learning system supporting individuals' learning (Buckler 1996). As an important feature of his model, Buckler (1996) emphasize a progressive process where participants reflects on questions: "What have we learned?" and "How have we learned?"

CIMA (Euro-Australian co-operation centre for continuous Improvement and innovation Management) proposes a methodology that maps the current level of learning and knowledge management (strengths and weaknesses) as a basis for intra-firm and inter-firm comparison (Boer et al. 2001). Furthermore, Boer et al. (2001) provide guidelines for improving learning and knowledge generation processes in product innovation. The CIMA operationalized the model in questionnaires and developed a knowledge base comprising data from more than 80 companies (Boer et al. 2001).

So far, the author has found no examples in literature applying prototyping or probe-and-learn processes for developing and integrating continuous improvement and innovation programs into ETO processes.

DATA AND METHODS

This study applied action research enabling a mutual learning process and a collaborative partnership between a scholar and a company (Bradbury & Reason 2003). Action research provides the company with self-help capabilities while the scholar gains access to real-life data (Coghlan & Brannick 2014).

The author designed the CII-program through four action research cycles, each comprising four steps: developing a construct, planning action, taking action, and evaluating action. Figure 1 illustrates an action research cycle. Subsequently, the author revised the CII-program and planned the next step (Coughlan & Coghlan 2002; Coghlan & Brannick 2014). The action research process was therefore applicable for a probe-and-learn development process for a CII-program.

Figure 1. Action research cycle of constructing, planning action, taking action, and evaluating action (Coughlan & Coghlan 2002; Coghlan & Brannick 2014).

RESEARCH DESIGN

A pre-step of understanding the context and purpose of the study was formed before executing cycles of constructing the issue, planning action, taking action, and evaluating action (Coghlan & Brannick 2014). Each action research cycle had a specific focus:

The 1st cycle aimed to scope the project together with the management team in the company to develop a mutual understanding of the company's challenges related to innovating effectively and for management to select a focus for applying the program.

The plan was to conduct semi-structured interviews with key informants, visit workplaces, and participate in meetings to gain insights into what challenges the organizational members were discussing and trying to solve as part of their daily work. Transcriptions of interviews and observations would then be analyzed and the findings presented to the company's management team. Figure 2 illustrates the first action research cycle.

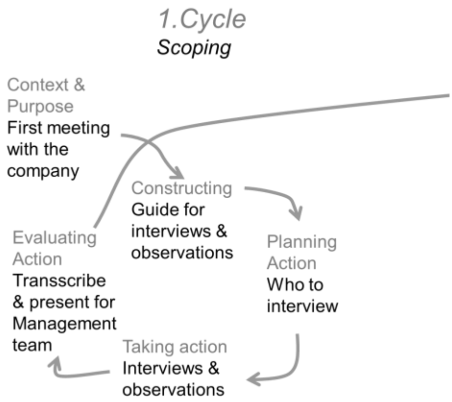

Figure 2. The first action research cycle included a first meeting with the company to prepare our collaboration, construct guides for interviews and observations, plan interviews, complete interviews and observations, transcribe interviews, and present preliminary findings to the management team.

The author completed four semi-structured interviews with the CEO, finance director, production manager, and engineering manager. The managers were asked about challenges in the company and their department. In addition, the author observed internal project meetings, shop floors, and engineering offices. Preliminary findings about the company's challenges were presented to the management team, who then defined the focus for applying the program in the following cycle.

The 2nd and 3rd cycle comprised interventions where prototypes of the CII-program were applied to problems the company found relevant. Design principles directed the author's development of the first prototype of the CII-program. The CII-program was refined between the two applications of the prototype.

The plan was to facilitate a series of interventions in each research cycle where the author facilitated the interventions in a group of organizational members working on a specific ETO project. These interventions were expected to solve specific problems in ETO processes and deliver data about the learning process in the CII-program. Figure 3Figure illustrates the process in the 2nd and 3rd cycle.

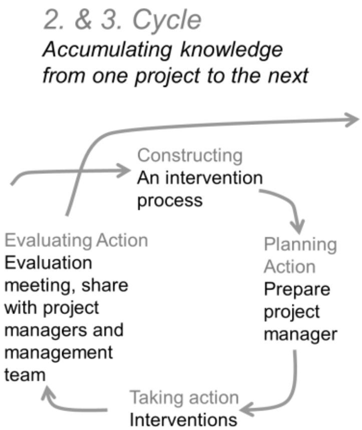

Figure 3. With input from the first action research cycle, the following two action research cycles applied prototypes of the CII-program in constructing an intervention process (the program), preparing the responsible project manager, applying the program in interventions, evaluating the activities with the project team, and sharing findings with other project managers and the management team.

In the first application of the CII-program (and 2nd cycle), a project team working on recurrent projects for a specific customer aimed to accumulating knowledge from one project to the next. The project team consisted of a project manager and three designers. The second application of the CII-program (and 3rd cycle) aimed to improve product quality as part of their daily work focused on developing an ETO process within a major project for a customer. The activities involved a project manager, a Lean manager, and employees from the assembly department. For both the 2nd and 3rd cycles, the study evaluated the activities with the participants, shared experiences with other project managers, and presented gained insights to the management team.

The 4th cycle comprised a test of a revised version of the CII-program, in which organizational members across functions solved problems related to ETO processes by following the steps in the program.

The plan was to test the CII-program by applying it to another ETO process emphasizing steps for developing and implementing solutions to problems identified in the first part of the study. Activities in the test were different from the first applications of the CII-program due to a revision of design criteria and program activities. Figure 4 illustrates the process in the 4th cycle.

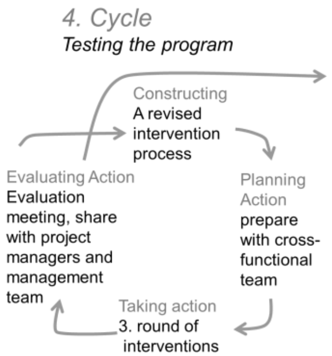

Figure 4. The fourth action research cycle tested the CII-program based on input from the previous cycles. The process included revising activities in the intervention process (CII-program), preparing activities with a cross-functional team, completing the test, evaluating the activities with the participants, and sharing findings with other project managers and the management team.

The final test of the CII-program involved a cross-functional group representing quality, production, logistics, and engineering functions. This cross-functional group prepared and planned the activities, elaborated on the design criteria defined by the management team, generated ideas, and developed prototypes of these ideas. The cross-functional group then presented selected solutions to a representative from the management team (production manager).

Activities in the four action research cycles generated data for this study, including transcribed interviews, observations, intervention dairies written by the author, and field data such as notes, pictures, and information collected about the organizational design. Two qualitative analyses of the collected data focused on challenges in a SME and an organizational learning perspective regarding the CII-program. The first analysis included inductive coding of data from the first action research cycle. The second analysis included a template analysis of data from the 2nd, 3rd, and 4th cycles using the 4I framework (Crossan et al. 1999; Zietsma et al. 2002). Analysis of the CII-program is not included in this paper.

THE CASE

A SME serves as a typical case illustrating the development process of a CII-program. The participating SME designs and manufactures customized equipment for the graphics industry. The company changed its strategic focus from single stand-alone projects to small, customized series of projects, where engineering increasingly reuses designs from previous customer projects. Management's objective is to sustain the SME's flexibility in delivering customized solutions while increasing the rate of standardization to improve efficiency. The application of the CII-program focused on sharing knowledge across functions in ETO processes. ETO processes involve organizational members of various functions such as sales, production, and naturally engineering. Recurring quality problems and delays in ETO processes could hurt the customer experience of products and thereby compromise the company's competitiveness. ETO processes have a short lead-time relative to new product development. In rapidly repeated ETO processes, it was possible to use the findings from one action research cycle in the next. Furthermore, the simple and organic organizational structure in a SME made the context relatively predictable and therefore favorable for applying prototypes of an incomplete CII-program.

In the first action research cycle, preliminary findings revealed conflicting interests and processes of trying to align these interests. The study identified three main challenges: First, four business units within the SME generated different needs in the business processes. Second, the board's expectations of a stable turnover combined with a short sight for new orders and volatile order income challenged resource management in engineering and production. Third, specialized knowledge about the customized equipment was stored as documentation in the projects and individually by engineers, thus limiting knowledge sharing. The management team chose the third topic as focus for the first series of interventions.

In the second action research cycle, the project manager's purpose for applying the program was to improve knowledge sharing within the project team in order to work more efficiently and use less hours for the design work. The project team designed equipment for a customer with several plants around the world. The project team worked on the eighth and ninth piece of equipment consecutively. Designers customized each piece of equipment for a specific factory. According to the project manager, 80% of the design work was "copy-pasted" from previous projects that had exceeded budgeted costs. The author prepared the project manager and facilitated the interventions. The interventions resulted in a board created to share knowledge on current projects. The project group evaluated the interventions at a one-hour workshop, where they summed up the interventions and handed over ideas for further improvements to a Lean manager. The project manager for the next application of the CII-program participated in the evaluation workshop. Additionally, the project manager and a member of the project group performed a self-assessment of the process. At the time of evaluation, two of the four members of the project group had left the company. The project manager presented findings at a regular meeting for other project managers. A one-hour standing meeting gave the management team a report back on findings. Findings from the second cycle provided the management team with information scoping the third cycle.

The third action research cycle focused on developing an ETO process within a major project for a customer. The project manager aimed to reduce recurring deviations in equipment design. Deviations are errors such as missing holes in parts that designers must correct in the documentation of the equipment. Participants highlighted two types of main issues in preventing reoccurring deviations. First, they questioned whether assembly actually registered all deviations rather than only correcting the errors, they found. It became obvious that not all technicians found it worth the trouble to file a registration in the IT-system, for in their experience, designers did not correct the deviations anyway. This latter complaint was the second issue, and participants tested both issues in the specific project. The test showed that assembly had registered the expected amount of deviations and that designers had taken action on registered deviations. However, when trying to test how many of the deviations reoccurred in the following project a few months later, the assembly leader found that another assembly leader had not registered deviations in the beginning of the project. Therefore, comparisons of the deviations in the two projects were impossible. Consequently, the management team raised an issue about divergence of role and responsibilities. Furthermore, overlapping projects caused delays in corrections when drawings for a project were reused (copied) before the first project was finished in assembly. The findings also confronted management team with a third issue about the importance of apparently insignificant deviations. Looking through deviations of the project revealed that 42% of the deviations regarded holes (e.g., placed wrong, missing, wrong diameter, missing thread).

In the fourth action research cycle, the management team scoped the task and formed a new cross-functional group to participate in testing the program. Scoping the task comprised of setting objectives and design criteria for solutions. The goal set by the management team was to achieve a shorter delivery time, fewer repetitive errors, and an improved ability to formulate brilliant ideas. The management team also set some guidelines regarding design criteria. The management team chose that the group should apply rapid prototyping, where some prototypes of the solutions constructed with "cardboard and paper" were tested.

The four participants in the group represented production, logistics, engineering, and quality functions with the quality manager as appointed leader of the group and the author as facilitator. The main activities included brainstorming solutions, creating a number of prototypes, testing the prototypes, and selecting 1-2 solutions based on the design criteria. The group focused on the deviation system and measuring its effects on two specific ETO processes. The group had 34 suggestions and chose to specify two prior to a presentation to management represented by the production manager.

EVALUATION OF DATA

During the study, it was of outmost importance to the author to base relationships with participants on mutual trust. The author spend considerable hours and days over two and a half year allowing the author and the researched organization to become closely acquainted.

Organizational members on mutual levels and across functions contributed to the CII-program design by taking part in and evaluating activities in the CII-program. The management team contributed by choosing a focus and in the test by selecting design criteria and methods. Participants in the interventions influenced program design through suggestions of tools and methods and by evaluating the activities in each action research cycle. Throughout the development process, the author used the metaphor “prototype” for the CII-program, making it apparent to participants that the CII-program was not finished work.

In this study, the author took the role of facilitator of interventions and researcher. As such, the author was both a researcher exploring the applicability of prototyping in developing a CII-program and a designer developing and testing a CII-program. Scholars can question whether research for this study truly is action research as the author developed the program at the home desk before applying prototypes.

The author’s ontological and epistemological assumptions were central to the choices made in this study. In this study, the author adopted a subjective perspective and understood the concept of learning as processes that continuously evolve based on individual and collective experiences. The subjective stance also included the author’s perception of organizations as collections of physical and social entities that also include social relations and processes. The author therefore humbly ask scholars to evaluate data in this study from this subjective stance.

RESULTS

The following section first presents the design criteria for developing the program, then the prototypes of the program applied in the case, and the final version of the program applied in the test.

DESIGN CRITERIA

Initially, the intention was to use a capability development approach where activities were limited in time and had a specific task and objective (Argyris & Schon 1996). Management should assign a specific task to a small group of participants. This group should involve “strangers” such as organizational members outside their own function (March 1991). The result or outcome of the activities, such as countermeasures to a problem, would be contained or coded into a work standard and the effect measured and monitored. The program should pay attention to the learning process in the management team, the organizational structure, mutual protection and trust, designate roles to the participants, and have management define the task and hand it over to a small group. In addition, the initial program emphasized framing and re-framing as core learning activities that could encourage explorative behaviors.

The design criteria were revised after applying prototypes of the CII-program twice. Eight design criteria directed the development of the final program. Criteria 1 to 4 concerned management scoping a task and setting the contextual stage for applying the CII-program (what, who, why, and when) (Argyris & Schon 1996). Criteria 1 proposed a task-focused design and criteria 2 specified a cross-functional design. Criteria 3 concerned authorization issues in a multi-level design and criteria 4 proposed integrating the CII-program into daily work. The following criteria 5 to 8 concerned the actual process within the program, as criteria 5 proposed encouraging divergent and convergent thinking for explorative and exploitative learning behavior (March 1991). Criteria 6 proposed an experimental design that encourage testing assumptions. Criteria 7 proposed a self-managing design that limited complexity for the participants. Finally, criteria 8 proposed awareness of organizational learning and knowledge processes (Crossan et al. 1999; Carlile 2002).

PROTOTYPES OF THE CII-PROGRAM

For the first applications of the CII-program, the prototype visualized a simple process where the participants contributed to clarifying and solving the problems and choosing methods for the problem-solving process. Figure 5 represents the planned process.

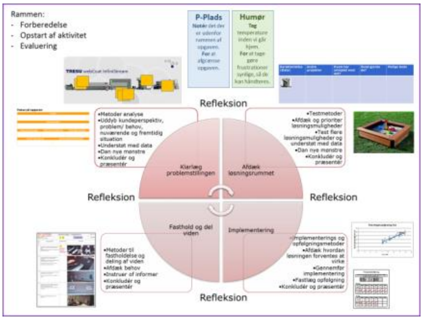

Figure 5. Illustration of the program used as the first prototype (text in Danish). There are four steps in the process: clarifying the problem, uncovering possible solutions, implementing, and sustaining and sharing knowledge.

The activity plan included hypotheses, expected results, and methods for measuring effect. The first CII-program application resulted in a board created to share knowledge on the current project. Although the project group was pleased with their work, they were not particularly explorative regarding testing problems with facts or considering various solutions. This meant that information on the board was scarce.

The second prototype of the CII-program followed the same agenda as the first prototype and added a storyboard visualizing the problem-solving process for the participants and other stakeholders. The second prototype used a large A0 sheet that functioned as a storyboard to direct the intervention process and contain findings of the problem solving. Each of the fields of the A0 sheet represent a step in a process to help participants examine and select problems and propose possible solutions. Figure 6 illustrates the second prototype.

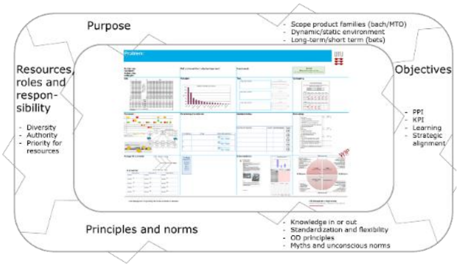

Figure 6. The second prototype clarified management scoping and visualized the problem-solving process on a storyboard.

The intention with the revised second prototype was to advance the testing of assumptions, especially those participants had about their colleagues in other functions. The goal was also to progress the process in order to reach the last two of four quadrants: implementation and sustain and share knowledge. Furthermore, the second prototype of the CII-program stressed the importance of scoping the problem-solving activities with management before initiating the activities and reporting outcomes to management afterwards. Figure illustrates the scoping with a broken frame around the storyboard, as it could be necessary to renegotiate the conditions for solving the problems. In addition, the scoping specified management's role in relation to improving ETO processes.

THE FINAL CII-PROGRAM

The final CII-program combines problem solving practices in design thinking (Brown 2008) and creative problem solving (Osborn 1957; Tassoul & Buijs 2007). The CII-program comprises five steps: 1) Prepare (Understand), 2) Clarify the gap (Define), 3) Design Solutions (Ideation), 4) Implement (Implementation), and 5) Evaluate (Test), as shown in figure 7. The CII-program aims to solve specific problems leading to gradual changes as part of daily development work.

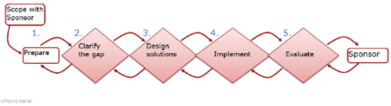

Figure 7: The five steps of the CII-program developed in a SME: Scope and prepare, Clarify the gap, Design solutions, Implement and Evaluate.

In step 1, prepare, the purpose of management scoping a task for applying the CII-program is to clarify intentions and ensure that the task makes sense to those involved. Management representatives scope application of the CII-program together with a facilitator and an appointed manager. In the preparation, the management representatives form a common understanding of the current state of, for example, the ETO process arguing for the importance of the task. Management representatives also form a common understanding of what they want to achieve with the program, while they also clarify which factors influence the task and what resources are available. Expectations for the outcome of the CII-program are stated as targets, process objectives, and learning objectives. Scoping the task ensures that an appointed cross-functional group can work rationally on the task. The visualized scope illustrated in Figure 8 directed the problem solving in the cross-functional group.

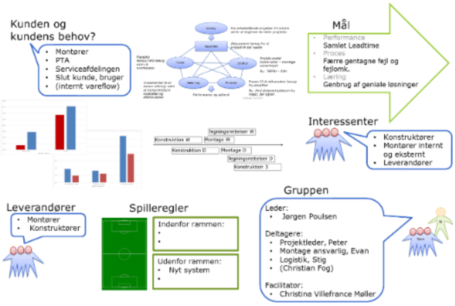

Figure 8. Management scoping the task (text in Danish).

Steps 2 – 5 comprise clarify gap, design solutions, implement, and evaluate. The following four steps in the CII-program aim at enhance participants' understanding of knowledge-sharing problems in ETO processes, explore more optional methods and solutions, select and implement a solution, as well as evaluate and share findings with others in the organization. The activities within each of the four steps support a rhythmic shift between divergent and convergent thinking. This means that, on the one hand, it is possible to propose several options (divergent) and select (convergent) options based on the design criteria. This divergent – convergent process is known as the double diamond or creative problem solving process (Osborn 1957; Tassoul & Buijs 2007).

Figure 9. Storyboard for the final program containing the steps in the CII-program

Again, a A0 (shown in figure 9) sheet functioned as storyboard helping the participants to keep track of the progress and findings in the CII-program. The steps formed a pulse of activities enabling divergent and convergent thinking (e.g. exploring possible root causes to a problem) followed by convergent thinking (e.g. prioritizing and selecting a cause).

DISCUSSION

Findings from the development process show that practitioners gain increased insight into cross-functional ETO-processes and the improvement process.

The fact that the design criteria, activities, and tools used in the CII-program are changed based on applications of prototypes does not itself confirm that prototyping is useful when developing a CII-program. However, in this case the following findings were gained from applying prototypes of the CII-program:

- Scoping application of the CII-program is a tool for engaging management in continuous

improvement and innovation of ETO processes.
- Using storyboards helps participants and the facilitator focus on the task instead of each other.
- Participants on all levels and across functions gained insight into their ETO processes.
- Participants on all levels and across functions also gained insight into each other's work, challenges, and interdependencies.
- The program designer (the author in this case) gained valuable feedback regarding gaining momentum in the program.
- The program designer gained valuable insights into practitioners' difficulties in developing their processes as part of their daily development work.

Furthermore, it became evident that participants and facilitators (in this case the author) constantly had to work on both a product level and a process level. The participants focused on both the equipment they were designing and the ETO-processes. The facilitator focused on the CII-program as a product supporting practitioners' development of their ETO processes. In addition, the facilitator focused on the program development process. These observations are relevant to compare with classifications of learning levels made by Gregory Bateson (Bateson 2000). According to Bateson (2000), "learning" implies a change that can be progressive or regressive in nature. Second-order learning is the ability of learning to learn, which means that the learning achieved in a context can be transferred to another context to become increasingly better at solving problems (Bateson 2000). Learning to learn in a new context entails a use of this habit and requires the creation of a new habit and possibly breaking the existing habit (Bateson 2000).

CONCLUSION

This paper contributes an in-depth description of applying prototypes in a probe-and-learn process of developing a CII-program.

Further research will include an organizational learning perspective of the learning process in the CII-program. An analysis will focus on the learning of integrating new organizational practices in daily ETO processes. Furthermore, research will comprise a similar development process in a large make-to-order manufacturing enterprise.

An interesting topic for further research could also be the study of paradoxical practices in the relationship between the Lean manager and the author as facilitator regarding the participatory process.

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REFERENCES

Argyris, C. & Schon, D., 1996. *Organizational learning II. Theory, method and practice*, Addison-Wesley Publishing Company,.

Bateson, G., 2000. The Logical Categories of Learning and Communication. *Steps to an Ecology of Mind*, p.279~308.

Bessant, J. & Caffyn, S., 1997. High-involvement innovation through continuous improvement. *International Journal of Technology Management*, 14(1), p.7.

Boer, H. et al., 2001. Knowledge and continuous innovation. *International Journal of Operations & Production Management*, 21(4), pp.490–504.

Boer, H. & Gertsen, F., 2003. From continuous improvement to continuous innovation: a (retro)(per)spective. *International Journal of Technology Management*, 26(8), p.805.

Bradbury, H. & Reason, P., 2003. Action Research: An Opportunity for Revitalizing Research Purpose and Practices. *Qualitative Social Work*, 2(2), pp.155–175.

Brown, T., 2008. Design thinking. *Harvard Business Review*, 86(6).

Çakar, N.D. & Ertürk, A., 2010. Comparing Innovation Capability of Small and Medium-Sized Enterprises: Examining the Effects of Organizational Culture and Empowerment. *Journal of Small Business Management*, 48(3), pp.325–359.

Carlile, P.R., 2002. A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science*, 13(4).

Coghlan, D. & Brannick, T., 2014. *Doing action research in your own organization* 4th Editio., London: Sage Publications.

Cole, R., 2002. From continuous improvement to continuous innovation. *Total Quality Management*, 13(8).

Coughlan, P. & Coghlan, D., 2002. Action research for operations management. *International Journal of Operations and Production Management*, 22(2), pp.220–240.

Crossan, M.M., Lane, H.W. & White, R.E., 1999. AN ORGANIZATIONAL LEARNING FRAMEWORK: FROM INTUITION TO INSTITUTION. *Academy of Management Review*, 24(3), pp.522–537.

March, J.G., 1991. Exploration and Exploitation in Organizational Learning. *Organization Science*, 2(1), pp.71–87.

Martini, A. et al., 2013. Continuous innovation: towards a paradoxical, ambidextrous combination of exploration and exploitation. *Int. J. Technology Management*, 61(1).

Osborn, A.F., 1957. *Applied Imagination*.

S. Adler, P. et al., 2009. Perspectives on the productivity dilemma. *Journal of Operations Management*, 27(2009), pp.99–113.

Tassoul, M. & Buijs, J., 2007. Clustering: An Essential Step from Diverging to Converging. *Creativity and Innovation Management*, 16(1), pp.16–26.

Ulrich, K.T. & Eppinger, S.D., 2012. *Product design and development*, McGraw-Hill/Irwin.

Willner, O. et al., 2016. Exploring the archetypes of engineer-to-order: an empirical analysis. *International Journal of Operations & Production Management*, 36(3), pp.242–264.

Zietsma, C. et al., 2002. The War of the Woods: Facilitators and Impediments of Organizational Learning Processes. *British Journal of Management*, 13(S2), pp.S61–S74.